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MOSLEY**

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be harmful

**PLASTIC
PLANET**

Is packaging fuelling
a fertility crisis?

FACEBOOK LEAKS CAN PSYCHOLOGICAL PROFILING TURN LIKES INTO VOTES?
PLUS HOW SOCIAL NETWORKS ARE BUILT TO MAKE YOU BINGE

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STEVEN SWANSON, NASA ASTRONAUT
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Silicon Valley techies don't tend to let their kids use social media → p58

WHAT WE'VE FOUND OUT THIS MONTH

There's a naturally occurring microbe that likes to eat crude oil → p21



Bodies decompose faster wrapped in rugs → p52



You can unboil an egg → p83



One in six couples in the UK have problems conceiving a child → p66



WELCOME



The Cambridge Analytica story has rocked the tech world. In case you haven't followed the revelations, here's a quick summary.

Aleksandr Kogan, a psychologist at Cambridge University, designed a Facebook quiz called 'This Is Your Digital Life' for "research purposes". He paid some 270,000 volunteers a few dollars each to answer his questions and give him access to their profile, their friend list and their friends' Likes.

Facebook estimates Kogan could have collected data from around 87 million profiles. This information powered a profiling tool that could use a handful of Likes to predict your personality type, and so suggest the kind of messaging that might convince you to buy a product or vote. A marketing firm called Cambridge Analytica got its hands on the data, and it's thought that it might have used this to tailor messages to voters during elections around the world.

While government agencies, journalists and others wrestle with the legalities of the above, it's been a sobering moment in regards to our relationship with social media. Whether your data was leaked or not, or whether you even have a Facebook account, there are interesting questions here. Can psychological analysis and demographic profiling persuade people to vote? Turn to p26 to find out.

And there's slightly bigger question to consider. This research was compiled five years ago, based on just our Likes. As deep-learning techniques learn to read text, understand it and draw conclusions, what could Facebook achieve with the information we've shared on the rest of our profiles since? And do we trust that they ultimately have our best interests at heart?

Daniel Bennett

Daniel Bennett, Editor

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LISA FELDMAN BARRETT

After publishing nearly 200 papers on the study of emotion, Lisa is convinced that happiness and sadness don't really exist. → p42



JHENI OSMAN

Jheni is a science writer who loves the natural world. She investigates whether pollution and plastics could lead to a global fertility crisis. → p66



CATHERINE PRICE

We know social media's bad for us, but we just can't stop checking our feeds. Science journalist Catherine reveals the design tricks that keep us hooked. → p58

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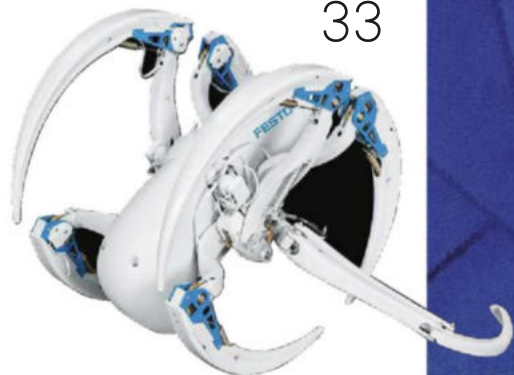
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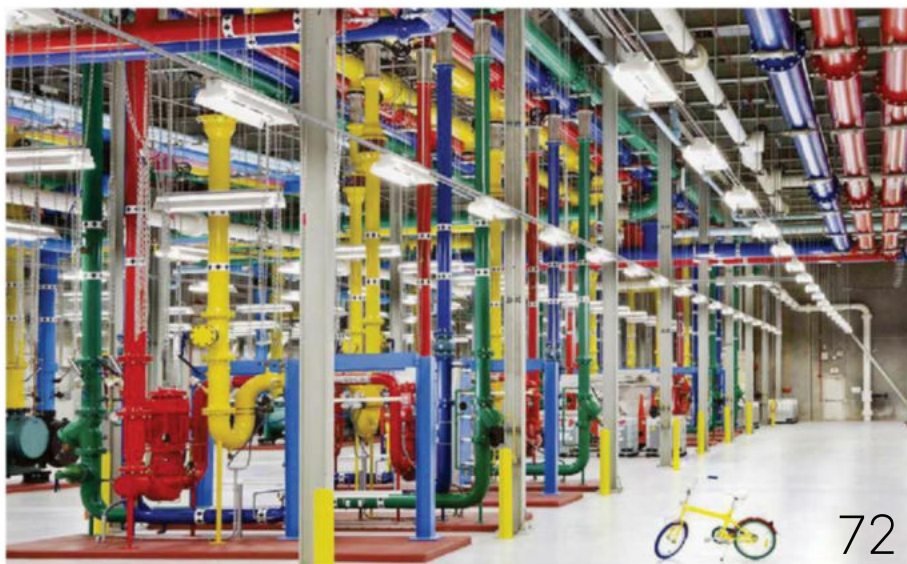
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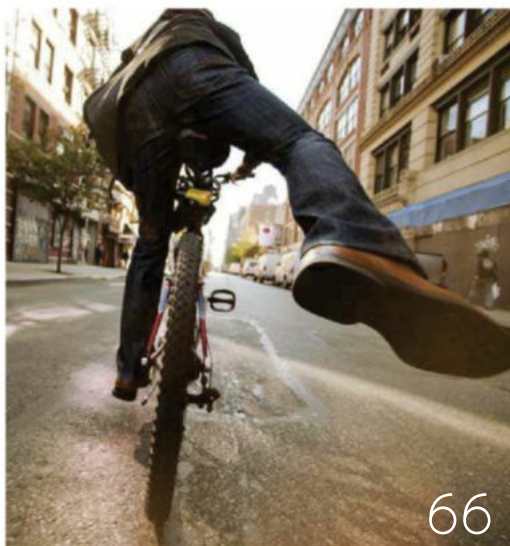
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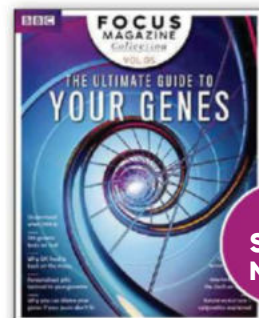
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Special issue



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COVER STORY

Fields of glass

WESTLAND,
THE NETHERLANDS

In 2000, the Netherlands committed to creating twice as much food using half as many resources. This was in response to concerns about food availability amid worldwide population growth. It's certainly delivered. By investing research in areas like LED lighting and climate control, Dutch farms – like those under the fields of glass seen here – can grow crops in any weather. In fact, the Netherlands is the second largest exporter of food as measured by value, second only to the US, which is 270 times its size.

Using techniques like hydroponics, which involves growing crops in a nutrient-filled solution rather than soil, Dutch farmers have reduced their water footprint too. Worldwide, it takes around 23 times more water to produce an average pound (0.45kg) of tomatoes than it does in the Netherlands.

The Plant Sciences Group at nearby Wageningen University works to improve every step in the food production chain, said communications advisor Erik Toussaint. "Growers use computer programs to predict crop growth, based on models developed by scientists. We also look into things like the best glass angle to get as little reflection as possible."

PHOTO: LUCA LOCATELLI / INSTITUTE







EYE OPENER

Colourful coral

MANADO, INDONESIA

The 'Coral Triangle' straddles the waters of Indonesia, Malaysia, the Philippines, Papua New Guinea, Timor Leste and the Solomon Islands. The region contains nearly 600 different species of coral, one of which is the red finger gorgonian, sprawled across this picture. Crawling over it is a spiky crinoid, also known as a feather star, which belongs to the same group as starfish. The gorgonian is a type of soft coral, and its white polyps trap plankton or bacteria, which it eats.

James Crabbe, emeritus professor and marine biologist at the University of Bedfordshire, said that although hard corals are suffering most under climate change, soft corals will also be affected, primarily due to ocean acidification rather than temperature change. "Soft corals often have small mineral cores [sclerites], which will become more brittle and therefore more susceptible to damage in storms. Taken all together, it's not good news for coral unless we do something about climate change."

PHOTO: JET LONG / SONY PHOTOGRAPHY AWARDS





EYE OPENER

Building blocks

UNIVERSITY OF NOTTINGHAM,
UNITED KINGDOM

These 20 x 20 x 20mm aluminium blocks are prototypes for the next generation of 3D-printed lattice structures.

The blocks were made at the University of Nottingham using a process called 'selective laser melting', which makes the structures strong but light. That's good for a lot of things: fuel efficiency of cars and planes, for example, increases when vehicle parts are lighter.

It's the patterns that make these blocks so effective. "You can align patterns to create strength in the direction you need it, but not in others," says BBC presenter and materials scientist Dr Mark Miodownik. "Sometimes you want things to collapse to absorb impacts, like a helmet or body armour. You can make structures weak in a particular place, so they'll crumple and absorb energy."

As 3D printing costs decrease, use of these structures will become even more widespread. "Anywhere you need to save weight and increase performance, these 3D-printed structures will be used. Planes, bicycles, body armour – everywhere really," says Miodownik.

PHOTO: SAM CATCHPOLE-SMITH



REPLY

Your opinions on science, technology and *BBC Focus*

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MESSAGE OF THE MONTH

Mind the gap

I love science and technology. I like everything: the science behind AI, medical advancements, even the chemistry of rotting cabbages and fish. There is, however, one area of science where I find myself vaguely disappointed: space exploration. As a child I watched the original *Star Trek* series and although now I cringe at the bad sets, silly stories, misogynistic attitudes and blatant sexism, these were ironed out of *Star Trek: The Next Generation*. In their place were tales of equalism, and a crew that had to work together to solve moral questions aplenty.

What all *Star Trek* series had, however, is advanced technology: warp drives, replicators, tractor beams and communicators. I know we have 3D printers, which may, in time, become replicators, and smartphones that probably outshine communicators. We also have computers we can operate with speech, similar to the one on the *USS Enterprise*. Incidentally, it always puzzled me why the bridge needed a crew if the computer was so advanced. Surely the captain could just address all commands to the 'computer'?

Star Trek set the bar because it was, in my young eyes, more fact than fiction. So when I read about the discovery of exoplanets and evidence of black holes or dark matter, or space probes exiting our Solar System, I always feel slightly disappointed that we're still so far behind our own imaginations.

Victoria Thorneon-Field, via email

There's certainly a gap between science fiction and what we can achieve with science in reality. Perhaps a better way to look at it is that we have such ambitious ideas and are racing to try and realise them, rather than lament how far short we seem to have fallen. (Good point about the computer and the crew though.)

— Daniel Bennett, editor

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **Minirig Mini rechargeable Bluetooth speaker**. It's small enough to fit in the palm of your hand, yet able to pump out an impressive 15W of power, and will be engraved with a *BBC Focus* logo. minirigs.co.uk



Forget the space probes, we want warp drives and tractor beams, says Victoria Thorneon-Field

Geoengineering? No, no, no!

I find Peter Irvine's ideas on geoengineering (April, p77) positively dangerous. They're naive and totally foolhardy. Human history is littered with instances where actions have been taken by people who claim to 'know best' only for later generations to have pick up the pieces when those actions have been shown to be harmful.

Irvine seems not to consider the possibility that wrong decisions could be made, or that there aren't always ways to correct them. He also sums his piece up by suggesting that anyone who objects to the course of action he's suggesting is simply being unnecessarily pessimistic. To my

mind, that says it all. I think his ideas should be consigned to the nearest bin.

Let's just leave nature alone to try to correct the mess we've so far made. Yes, minimise the continuing problem, but don't let us assume we know how to correct anything beyond that.

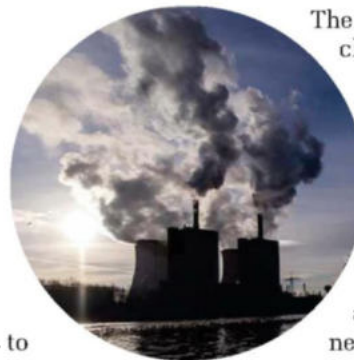
Hally Hardie, via email

Solutions create problems

The 'quick fixes' to climate change

suggested in April's issue are attractive but the way I see it is they're likely to lead to further problems. For example, nations are never going to agree on what action needs to be taken and

who needs to take it. They can't even effectively agree on CO₂ limitation and any unilateral



action will surely lead to conflict, if not outright war.

And what happens if (almost certainly when) any unexpected and undesirable side effects of geoengineering start to appear? Will they be reversible? Will we be able to remove/counteract the SO₂ aerosols we spray into the atmosphere? I suspect not.

Hilary Gee, Grange-over-Sands, Cumbria

You smell nice

In your response to James Goodman's letter (April), you say it is unclear how we could smell a gene. I suggest it's not the gene that we smell but what the gene produces – a protein or peptide, which is a component of that individual's semiochemical signature. These pheromones are known to be a cocktail of low-molecular-weight hydrocarbons and peptides or conjugated peptides. The peptide component would be a useful marker of the genetic differences between individuals. Choosing a mate whose genes are very different conveys the advantage of genetic diversity.

David Shepherd, via email

Evidence suggests that turmeric could be beneficial for your health – it's not just a hipster fad

Turmeric treatment

Michael Mosley's article on turmeric (March, p28) was brought to my attention by a friend who knew I had an interest. About two years ago my hands began to stiffen and become painful. An Indian friend suggested including turmeric in my diet and after a little online research and a test run of turmeric capsules, I decided to use what's known as a golden paste – a cooked mixture of turmeric, water, coconut oil and black pepper. As there's some suggestion that the spice only remains active in your system for about six hours, I take a third of a teaspoon in milk, three times a day.

After a couple of weeks both the stiffening and pain disappeared and so far they remain absent. It's possible there might simply have been a placebo effect at work but this wouldn't explain why a long-standing, undiagnosed rash on my calf disappeared and a weak vein in my nose became less problematic.

Stan King, via email

➔ It's brilliant that turmeric has helped, Stan. Hope you enjoy Michael's column this month too. – **Daniel Bennett, editor**



BBC FOCUS

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BBFPRASY18

DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

MAY 2018

EDITED BY JASON GOODYER

A glacier exiting
the Devon Ice Cap
in Canada, where the
research took place

SPACE

UNTOUCHED SUBGLACIAL LAKES COULD HARBOUR CLUES TO EVOLUTION OF ALIEN LIFE

Vast bodies of water more than 500 metres below
the Arctic ice may host life forms that have evolved
independently for 120,000 years

ALAMY

Two isolated salt lakes that have been discovered beneath the ice in the Canadian Arctic may help us to understand how alien life could have potentially evolved on one of Jupiter's moons, a team from the University of Alberta say.

After analysing radar data originally acquired by NASA to investigate the bedrock conditions beneath the ice cap, the team found two lakes located 550 to 750 metres below the Devon Ice Cap, one of the largest ice caps in the Canadian Arctic.

There are some 400 known subglacial lakes in the world, mostly scattered around Antarctica, but the Devon Ice Cap lakes are the first to be found in the Canadian Arctic and the first thought to contain salty water.

"We weren't looking for subglacial lakes. The ice is frozen to the ground underneath that part of the Devon Ice Cap, so we didn't expect to find liquid water," said lead researcher Anja Rutishauser. "We saw these radar signatures telling us there's water, but we thought it was impossible that there could be liquid water underneath this ice, where it is below -10°C ."

One lake is around five square kilometres in size, while the other is larger in area at roughly eight square kilometres. The water contained in them is able to remain liquid at such low temperatures thanks to its high salt content – around four to five times that of seawater.

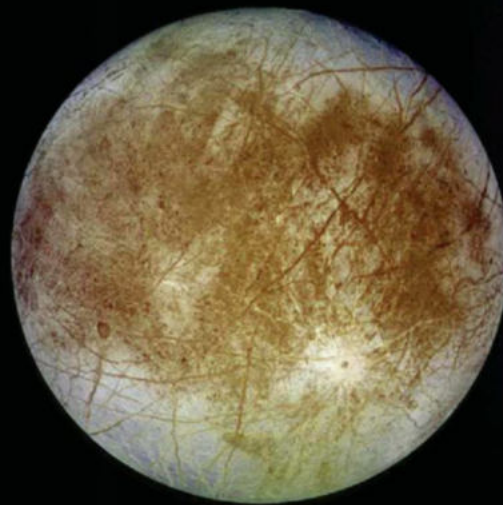
Most intriguingly, the lakes could potentially play host to microbial life that evolved in isolation. Studying such forms of life could provide researchers with an invaluable resource in the search for life beyond Earth. Though all subglacial lakes are thought to be potential contenders for the existence of strange microbes, the extreme saltiness of the water in the Devon Ice Cap lakes makes them particularly promising analogues for the ice-covered moons found in our Solar System.

"We think they can serve as a good analogue for Europa, one of Jupiter's icy moons, which has similar conditions of salty liquid water underneath – and maybe within – an ice shell," said Rutishauser. "If there is microbial life in these lakes, it has likely been under the ice for at least 120,000 years, so it likely evolved in isolation. If we can collect a sample of the water, we may determine whether microbial life exists, how it evolved, and how it continues to live in this cold environment with no connection to the atmosphere."

The team now plans to undertake a more detailed airborne geophysical survey over the Devon Ice Cap to further study the lakes and their geology and composition.

EUROPA

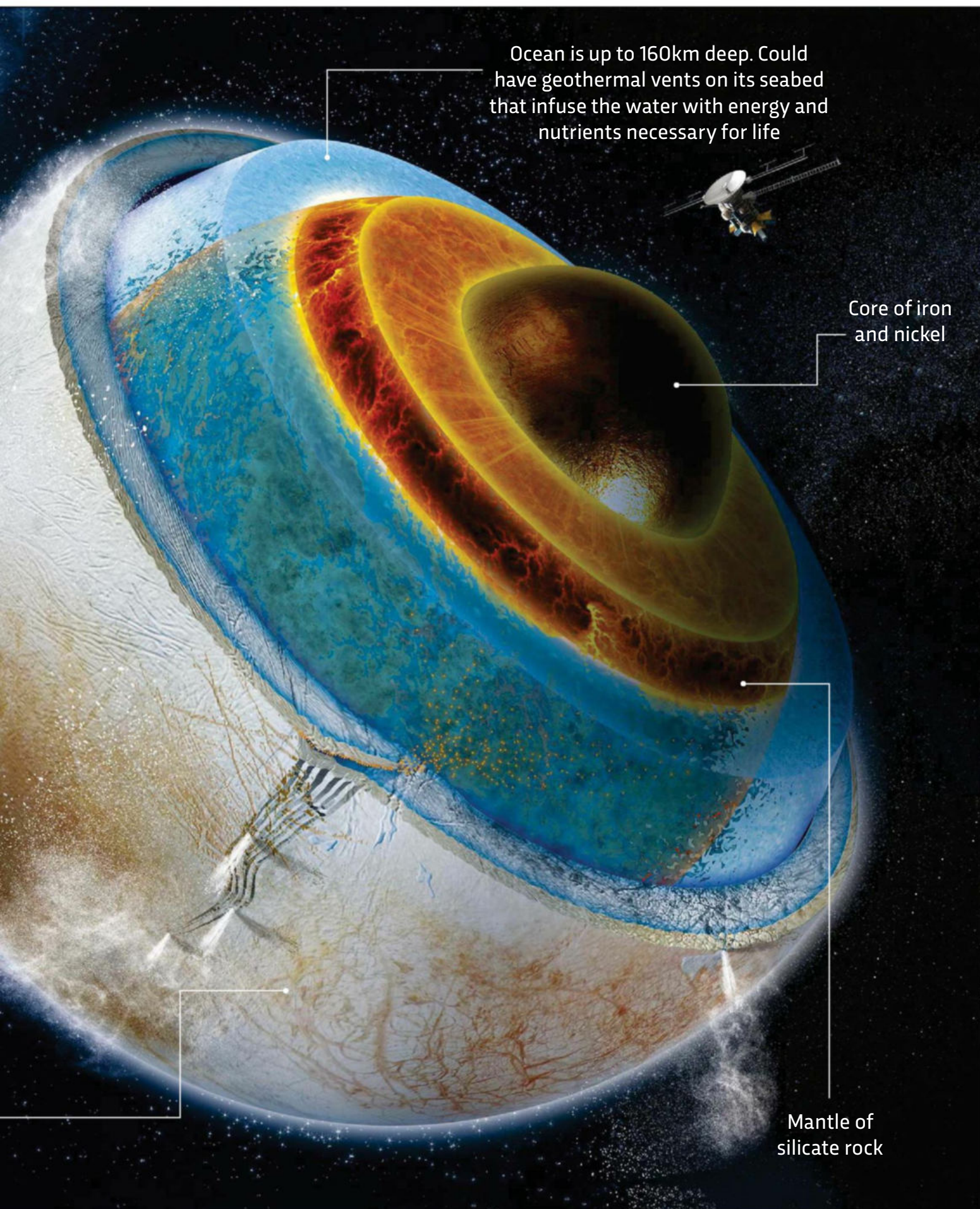
Jupiter's moon Europa is home to an ocean buried beneath its ice crust. Scientists believe this water could be a good potential location to hunt for alien life...



Jupiter's moon Europa is slightly smaller than our Moon. It is the smallest of the four largest moons of Jupiter, and was discovered by Galileo in 1610

Thin, oxygen-rich atmosphere

Ice crust is 10-30km thick



Ocean is up to 160km deep. Could have geothermal vents on its seabed that infuse the water with energy and nutrients necessary for life

Core of iron and nickel

Mantle of silicate rock



PALAEOLOGY

Dinosaur footprints found on the Isle of Skye are shedding light on the Jurassic period

PERFECTLY PRESERVED DINOSAUR FOOTPRINTS FOUND ON SCOTTISH ISLAND

This really is like walking in the footsteps of giants: dozens of dinosaur footprints dating back around 170 million years have been found in a shallow lagoon on the coast of the Isle of Skye in Scotland's Inner Hebrides. Researchers from the University of Edinburgh measured, photographed and analysed about 50 footprints in a tidal area at Brothers' Point – a dramatic headland on Skye's Trotternish peninsula.

The find is globally important as it's rare evidence of the Middle Jurassic, from which few fossil sites have been found, they say.

In order to overcome the difficult tidal conditions, the researchers used drones to photograph and map the site. They then used a paired set of cameras, along with specialised software, to produce 3D models of the footprints. They identified two defined trackways and many other isolated footprints.

"The more we look on the Isle of Skye, the more dinosaur footprints we find," said the University

of Edinburgh's Dr Steve Brusatte. "This new site records two different types of dinosaurs – long-necked cousins of the *Brontosaurus* and sharp-toothed cousins of the *T. rex* – hanging around a shallow lagoon, back when Scotland was much warmer and dinosaurs were beginning their march to global dominance."

By analysing the clearest prints, the team was able to determine the overall shape of the track outline, the shape and orientation of the toes, and the presence of claws.

"This tracksite is the second discovery of sauropod footprints on Skye. It was found in rocks that were slightly older than those previously found at Duntulm on the island and demonstrates the presence of sauropods in this part of the world through a longer timescale than previously known," said study leader Paige dePolo. "This site is a useful building block for us to continue fleshing out a picture of what dinosaurs were like on Skye in the Middle Jurassic."

NANOTECHNOLOGY

START YOUR EN-GENES!

Riding a unicycle is an impressive feat under normal circumstances. But it's especially so when the contraption is only 30 nanometres in size (one nanometre = one-millionth of a millimetre). And that's just what has been built by a team of scientists split between the University of Michigan in the US and Germany's Caesar Institute and University of Bonn.

The team, led by Prof Michael Famulok, constructed the tiny vehicle using a pair of self-assembling DNA rings. Aside from its size, the tiny vehicle also differs from its full-size counterpart in the way it's propelled – instead of pedal power, the nano-unicycle is motorised.

“One ring fulfils the function of a wheel, the other drives it like an engine with the help of chemical energy,” said Famulok. “This is a big step: it's not easy to reliably design and realise such a thing on a nanometre scale.”

The protein T7 RNA polymerase serves as fuel by coupling to the ‘engine’ ring. The enzyme synthesises an RNA strand based on the DNA sequence and the chemical energy released in the process drives the ring's rotational movement. As the RNA strand grows it forms an ‘exhaust’ that can be used to steer the tiny unicycle.

On its first test drive the nano-unicycle covered 240 nanometres (for a sense of scale, a sheet of paper is about 100,000 nanometres thick) but it's not very fast – one turn of the tiny wheel took approximately 10 minutes.

Possible applications for this emerging technology include molecular computers or tiny machines that can transport drugs through the bloodstream.

IN NUMBERS

421,000

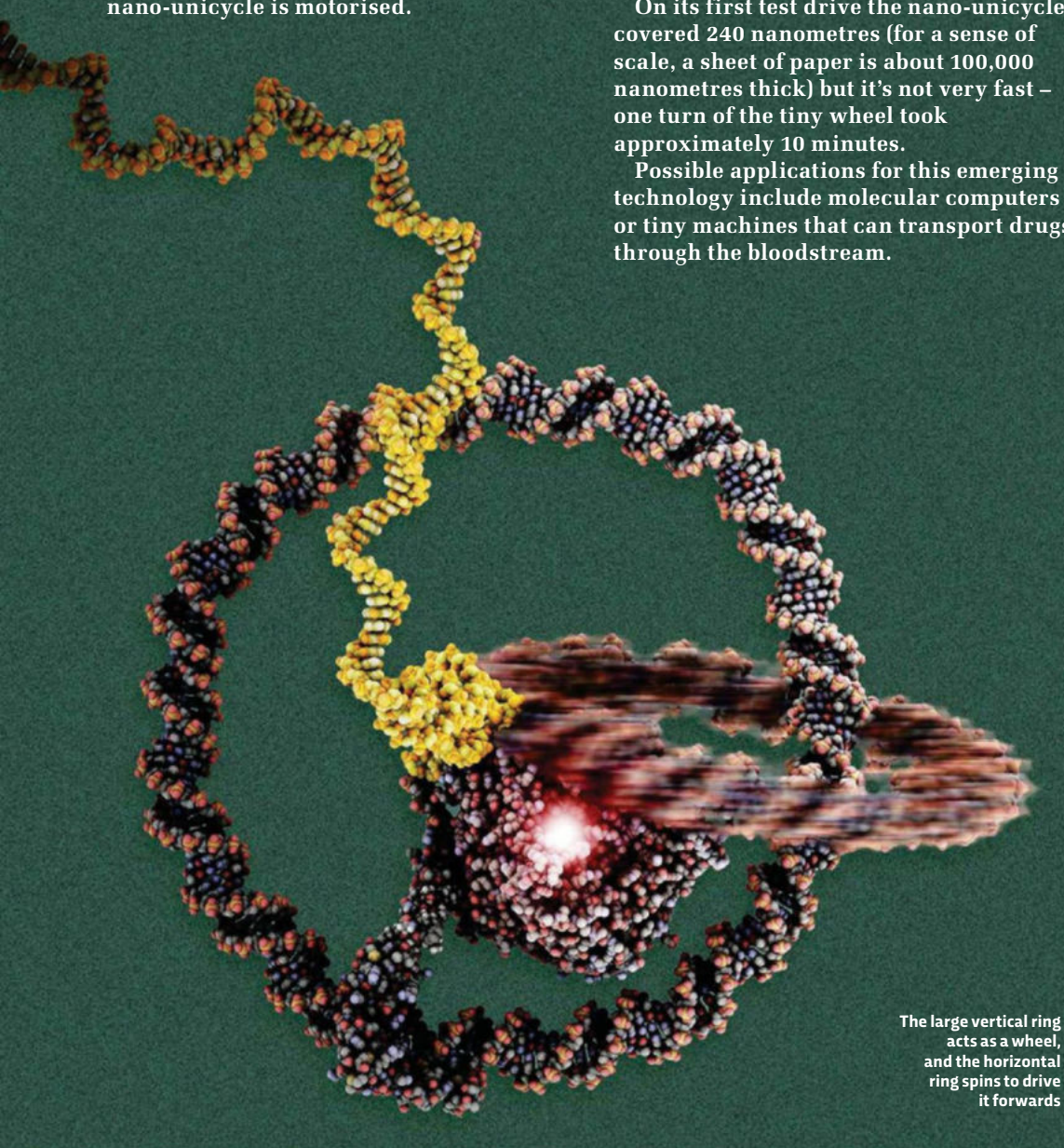
The number of bacterial cells found on the outside of the average person's shoes, as discovered by a team at the University of Arizona. Among them were potential harmful varieties such as *E. coli* and *C. diff*.

200
HOURS

The time we need to spend with an acquaintance before they become a true friend, according to a study carried out at the University of Kansas.

30
PER
CENT

The amount of plastic bags found in marine litter in UK seas has dropped by this percentage since 2010.



The large vertical ring acts as a wheel, and the horizontal ring spins to drive it forwards

GREEN-HAIRED 'PUNK' TURTLE ADDED TO ENDANGERED LIST

The Mary River turtle, an Australian reptile that can stay underwater for up three days, thanks to its ability to breathe through gill-like organs in its genitals, has been added to a list of the world's most vulnerable reptile species by the Zoological Society of London (ZSL).

The turtle, which can only be found in the Mary River in Queensland, was listed as the 30th most endangered reptile by the ZSL's EDGE of Existence programme. This initiative uses a complex formula to highlight species that are particularly 'evolutionarily distinct and globally endangered'. Each species is given a score, which combines extinction risk with a measure of how isolated or unusual it is on the tree of life.

"Reptiles often receive the short end of the stick in conservation terms, compared with the likes of birds and mammals," explained EDGE reptiles coordinator Rikki

Gumbs. "However, the EDGE reptile list highlights just how unique, vulnerable and amazing these creatures really are."

Topping the list overall, with an EDGE score higher than that of any amphibian, bird or mammal, is the Madagascan big-headed turtle. Other additions include the gharial, a freshwater crocodile once common across much of Asia but now confined to a handful of rivers in northern India and Nepal, and the Round Island keel-scaled boa, a non-venomous snake found in Mauritius that can change colour over a 24-hour period.

"Just as with tigers, rhinos and elephants, it is vital we do our utmost to save these unique and too often overlooked animals," said Gumbs. "Many EDGE reptiles are the sole survivors of ancient lineages, whose branches of the tree of life stretch back to the age of the dinosaurs. If we lose these species there will be nothing like them left on Earth."

The Mary River turtle often has strands of green algae growing on its head, resembling a mohawk



BIOLOGY

OIL-EATING MICROBE COULD HELP TO CLEAN UP OCEAN SPILLS



Crude oil spills have a devastating effect on marine life and can prove incredibly difficult to clean up effectively. But now, researchers based at Canada's National Institute of Scientific Research (INRS) have come up with a novel solution: team up with *Alcanivorax borkumensis*. This bacterium feeds on hydrocarbons, which make up most of the compounds in crude oil.

They found *A. borkumensis* after poring over the data sheets of countless bacteria strains, looking for those with genomes that produce specific types of enzymes that classify them as 'hydrocarbonoclastic', meaning they use hydrocarbons as a source of energy.

A. borkumensis accumulated a range of specific enzymes over its evolution that degrade almost all of the components found in crude oil.

Interestingly, it is found in all of the world's oceans and drifts with the current, multiplying rapidly in areas where the concentration of oil compounds is high. This may partly explain the natural degradation of crude oil that has been observed after some past spills. But until now, the oil-eating properties of *A. borkumensis* had never been tested.

"The degradation of hydrocarbons using the crude enzyme extract is really encouraging and reached over 80 per cent for various compounds," said Prof Satinder Kaur Brar, who led the research. "The process is effective in removing benzene, toluene, and xylene, [some of the harmful chemicals found in crude oil] and has been tested under a number of different conditions to show that it is a powerful way to clean up polluted land and marine environments."

THEY DID WHAT?!



MONKEYS' BATHING HABITS SCRUTINISED

What did they do?

A team of researchers at Japan's Jigokudani Monkey Park recorded the bathing habits of a group of Japanese macaques. In particular, they tested how levels of glucocorticoids, hormones associated with stress and body temperature management, varied as the animals bathed.

Why did they do that?

In 1963, the monkeys were first observed taking extended dips in the natural hot springs that occur in the mountainous areas of Japan. It was always assumed they did this to warm themselves up in order to cope with the low temperatures during the winter months, but this hypothesis had never previously been tested.

What did they find?

They found that monkeys who took regular baths displayed lower levels of glucocorticoids. This suggests that, as well as helping to keep the animals warm, hot spring baths also help to lower the animals' levels of stress.

MEDICINE

"This is a novel antibiotic so there will be no resistance"

Biologists have found a protein in platypus milk with an unusual structure. Dr Julie Sharp of Deakin University believes it can fight drug-resistant bacteria

ABOVE: Platypuses are native to freshwater regions in eastern Australia. They are the only surviving species in their family

What makes the duck-billed platypus so unique?

Platypuses do not have live birth, they lay an egg. When the egg hatches, the baby is underdeveloped – it's barely got limbs. Rather than having a placenta, which delivers nutrients and developmental factors, the young drinks solely milk. Marsupials [such as kangaroos] give birth to immature young as well, but when it reaches the pouch it attaches to a teat. Monotremes [the group consisting of platypus and echidnas] have no nipple for delivering milk – the milk is secreted onto the abdomen of the mother. It's called a 'milk pad': the milk will pool into a little area and the young will lick it from there.

The egg is not laid in a nest, it's still stuck to the abdomen of the mother, so when the young hatches it's exposed to the bacteria that's present in the environment and on her stomach. The baby's got an undeveloped immune system, so rather than fighting any infection, the milk is doing it.

How did you discover the so-called 'monotreme lactation protein'?

We were looking at platypus and echidna milk for what might aid development and survival of these young through to weaning. When milk is produced,

some cells from the mammary gland slough off. From these cells, we can find out what the mammary gland is producing. The white colour of the milk comes from casein proteins, and the monotreme lactation protein is just as abundant. So, we took that particular gene [for monotreme lactation protein] and put it in bacteria to express the protein itself, so we're now no longer dealing with milk. Then we purify the protein and it goes into a range of biological assays. From there we found that it was antimicrobial.

Why is monotreme lactation protein special?

It looked different in terms of the amino acid sequence – the building blocks of the protein. We approached the CSIRO [Commonwealth Scientific and Industrial Research Organisation] and asked them to do the crystal structure – how it folds in a 3D form. The CSIRO found a 'Shirley Temple' fold not seen in any other species, which is unusual because a lot of proteins use similar folds. It's called a Shirley Temple fold because it has a helical structure that resembles the long, circular curls in her hair. We can isolate that region and work out if it's responsible for the antimicrobial activity.



BELOW: When diving, platypuses close their ears and eyes, and rely on their sensitive bill to forage for invertebrates. Their thick, waterproof fur keeps them warm



DIGESTED READ

Platypus milk contains a protein that's unlike anything seen in the milk of other mammals. Scientists think that this 'monotreme lactation protein' could help in the fight against superbugs that are immune to current antibiotics.

How would the protein help fight drug resistance?

Because there have been a lot of antibiotics used in the past, and they all have similar structures, bacteria have learnt how to put up a defence against them. Monotreme lactation protein is a novel protein that hasn't been used in the

antibiotic area before; the bacteria won't have seen it, so there will be no resistance. It will take 10 or 15 years of exposure for bacteria to build up a resistance – if they can. We don't know the mechanism of killing, and we don't know if the bacteria are capable of putting up a defence against that. These are the unknown areas that we will be doing further research into, to try and work out how useful it will be in the future.



THE SHY

For some, the mere thought of asking a shop assistant a question can bring on sweaty palms. But help is at hand. A team at Carnegie Mellon University found that by pretending to be an observer rather than a participant in the interaction, the chronically shy can overcome feelings of embarrassment.

YOUNG MUSICIANS

Kids who take structured music lessons are ahead of non-musical peers in almost all areas of academic study including visual arts, organisational skills and language-based reasoning, a Dutch study has found.

GOOD MONTH

BAD MONTH

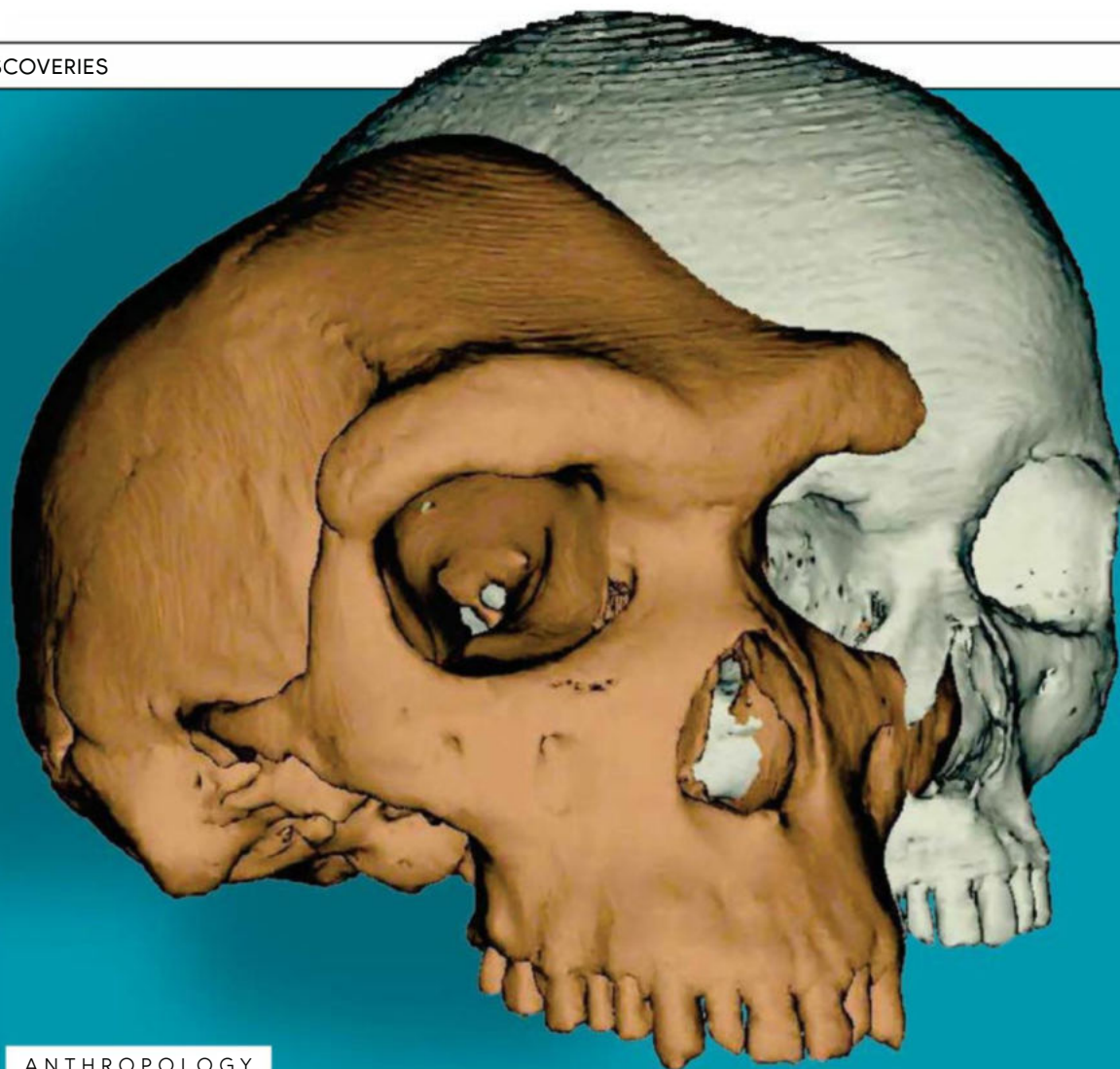
SEAFOOD LOVERS

The carbon footprints for eating most fish are typically relatively low. But prawns and lobster are just as bad for the climate as beef, a study at the University of British Columbia has found. The effect is down to the extra fuel used when catching them, as so few are harvested on a single trip.

PHUBBERS

'Phubbing' (snubbing others in favour of your phone), leads to the 'phubbee' perceiving communication quality to be lower and their relationship with the 'phubber' to be less satisfying, a team at the University of Kent has found. Better put that phone away.





Modern human skull (white) compared to *Homo heidelbergensis* (brown), which has a much more prominent brow ridge

ANTHROPOLOGY

MOBILE EYEBROWS MAY HAVE HELPED EARLY HUMAN ANCESTORS TO SURVIVE

It looks like Groucho Marx was onto something: mobile, expressive eyebrows help humans to communicate subtle emotions and may have played a crucial role in the survival and success of human ancestors, research from the University of York suggests.

Our early ancestors sported pronounced brow ridges, which, like the antlers on a stag, were seen as a signal of dominance and aggression. In contrast, modern humans have a much smoother forehead with eyebrows capable of a much greater range of movement, able to express a range of subtle emotions. This allowed humans to establish large social groups, and may have been key in allowing us to out-compete the now extinct Neanderthals.

The team used 3D-scanning software to map the pronounced brow ridge of Kabwe 1, a skull belonging to a species of archaic hominin, *Homo heidelbergensis*, that lived between 600,000 and 200,000 years ago.

“EYEBROW
MOVEMENTS
ALLOW US
TO EXPRESS
COMPLEX
EMOTIONS
AS WELL AS
PERCEIVE THE
EMOTIONS
OF OTHERS”

It has previously been proposed that the strong ridge was either to fill in the space between *Homo heidelbergensis*'s brain cavities and eye sockets, or to help stabilise their skulls while they chewed. However, computer simulations suggested neither of these to be the case, leaving the team to conclude that the ridges became less pronounced to help our ancestors communicate.

“Eyebrow movements allow us to express complex emotions as well as perceive the emotions of others. A rapid ‘eyebrow flash’ is a cross-cultural sign of recognition and openness to social interaction and pulling our eyebrows up at the middle is an expression of sympathy. Tiny movements of the eyebrows are also a key component to identifying trustworthiness and deception,” said study co-author Dr Penny Spikins. “Eyebrows are the missing part of the puzzle of how modern humans managed to get on so much better with each other than other now-extinct hominins.”

ASTRONOMY

CIGAR-SHAPED INTERSTELLAR ASTEROID LIKELY STARTED ITS JOURNEY IN A BINARY STAR SYSTEM

The mysterious cigar-shaped interstellar asteroid discovered hurtling through the Solar System at more than 100,000km/h last October is likely to have come from a two-star system, according to Canadian researchers at the University of Toronto, Scarborough.

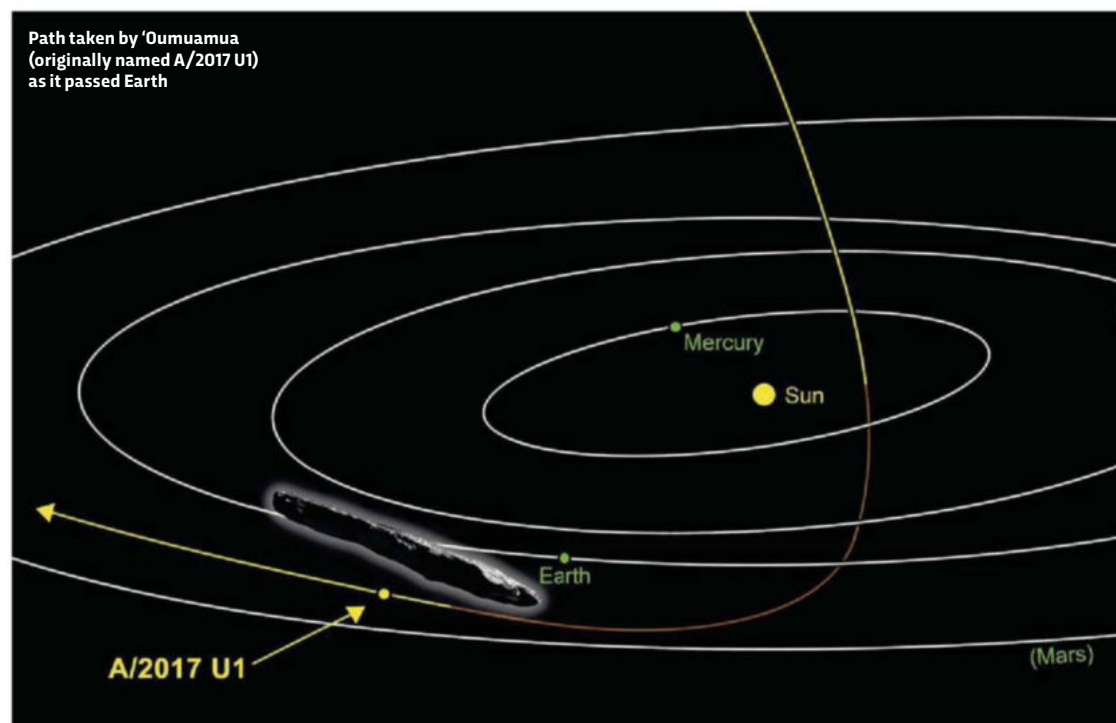
'Oumuamua, which is Hawaiian for 'scout', was first spotted by the Haleakala Observatory in Hawaii in October last year, and at its closest the asteroid was about 33,000,000km from Earth. It was initially assumed to be a comet – small, icy bodies that release gases as they are warmed up when passing close to the Sun. However, when it failed to show any comet-like activity, it was reclassified as an asteroid, meaning it was rocky.

Later, based on its trajectory and speed, it was determined that it must have come from outside of the Solar System.

Now, the Canadian team has determined that the asteroid most likely came from a binary star system – a system made up of two stars locked in orbit around a common centre. They found that rocky objects like 'Oumuamua are far more likely to come from binary than single star systems. And that the asteroid was likely to have been ejected from its home star system sometime during the formation of planets.

"It's really odd that the first object we would see from outside our system would be an asteroid, because a comet would be a lot easier to spot and the Solar System ejects many more comets than asteroids," said lead author Dr Alan Jackson.

"The same way we use comets to better understand planet formation in our own Solar System, maybe this curious object can tell us more about how planets form in other systems."



THINGS WE LEARNT THIS MONTH

BIG CATS ARE ATTRACTED TO AFTERSHAVE

Researchers at big cat conservation group Panthera have found that jaguars are more likely to spend time around camera traps that have been sprayed with cologne. This is due to the scents containing similar chemicals to pheromones produced by the cats. Their favourite fragrance? Calvin Klein's Obsession for Men.

DOGS LIE TO GET WHAT THEY WANT

Maybe they aren't such good boys after all: dogs are willing to deceive humans if their favourite snacks are at stake, Swiss researchers have found. When asked by human trainers to lead them to one of three boxes – one containing a favourite food, one that was empty, and one containing a non-favourite food – the dogs would show them the non-favourite food in an effort to keep the best snacks for themselves.

HUMANS PRODUCE NEW BRAIN CELLS THROUGHOUT THEIR LIVES

Columbia University has found that older people generate the same amount of new neurons as youngsters. They removed the hippocampus, a region of the brain associated with memory, of 28 people aged from 14 to 79 shortly after death. All of the samples had a similar number of neurons regardless of their age.

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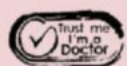


In each episode, we talk to some of the brightest minds in science about the ideas shaping our future:
Exoplanets • Altruism • Moon bases • Transhumanism • Psychosis
and much, much more

"IS IT OKAY TO CUT OUT COW'S MILK?"



DR MICHAEL MOSLEY



Michael is a science writer and broadcaster, who presents *Trust Me, I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* (£8.99, Short Books).



Recently, I read that scientists have identified a protein in platypus milk that can kill off drug-resistant bacteria (see p22). It's hoped that one day this novel protein could be used to create a drug to take on the superbugs. This is good news, as long as you are not a platypus. I fully expect platypus milk to become the next superfood. Platypus latte, anyone?

Milk used to be simple. It was the white stuff that came out of cows which you added to your tea or poured on top of your cereal. Then cow's milk began to get a bad press, first because of fears around saturated fat, followed by worries that it might trigger lactose intolerance.

For those who haven't been following this particular health scare, cow's milk is rich in lactose and if you lack the enzyme lactase (which, to be fair, many people do) then your body will find lactose difficult to break down and absorb. The bacteria in your gut will feast on the lactose, producing gas and irritating the gut.

All of which means that increasing numbers of people have excluded dairy products from their diet, but I fear this could have serious health consequences

for the next generation. Cow's milk has lots of nutrients, which milks derived from soya, almonds or oats don't, including a particularly important one – iodine.

A study carried out by the University of Surrey looked at the iodine content of 47 'healthy' milks (including soya, coconut, almond, rice and oat milk) and found they had levels of iodine that were 2 per cent of those in cow's milk.

Cow's milk remains the main source of iodine in the British diet. However, thanks to the move away from drinking it, the UK now ranks in the top 10 most iodine deficient nations in the world. This is worrying because the effects of being iodine deficient can be profound and long-lasting. Iodine is essential for the production of thyroxine, a hormone that controls all the metabolic processes that go on in your body and in particular your metabolic rate. What's worse is that even mild iodine deficiency in a pregnant woman can have a major impact on the brain of her developing foetus. Other countries, recognising this problem, add iodine to salt. We don't.

Goat's milk is also high in iodine – good news for people who find they struggle with cow's milk but can drink goat's milk with no issues.

So how do you get more iodine in your diet if you are lactose-intolerant, vegan, or just don't like cow's milk? The main alternatives normally offered are white fish or seaweed. But will they do the job? On *Trust Me, I'm A Doctor* we like to test these things out. So with the help of Dr Emilie Combet from Glasgow University we recruited some brave volunteers.

On three separate test days, our volunteers ate a carefully measured portion of one of these foods. Then, because iodine absorption is best measured by looking at urine, our volunteers had the delightful task of collecting all the urine they produced over the next 36 hours.

So what happened? Well, our volunteers' bodies did manage to successfully extract most of the iodine from the milk and the fish, but not from the seaweed. This is bad news for those who don't like milk or white fish, as other foods contain iodine in low and unpredictable quantities. This is why the Vegan Society recommends taking an iodine supplement.

Personally, I am going to stick to drinking the white stuff. ☺

PSYCHOLOGY

CAN LIKES BECOME VOTES?

At the end of March, Facebook took out full-page adverts in UK and US newspapers, apologising for data leaks

Marketing firm Cambridge Analytica convinced its customers that they could use data mined from Facebook to influence people's votes, but do their psychological profiling techniques really work?

Your Facebook data could be revealing more about you than you realise. But could it be used to persuade you to change your vote?

Data-driven marketing and political consulting firm Cambridge Analytica hoped it could. But now, the firm is facing a backlash after it was revealed that it had amassed data on tens of millions of Facebook users.

DATA HARVEST

The data came from 'This Is Your Digital Life', a personality quiz app created by neuroscientist Dr Aleksandr Kogan. If you gave the app permission to collect your Facebook data, thanks to the way the social network worked at the time, it was able to gain access to all of your friends' data as well. Kogan later started working with Cambridge Analytica, giving the firm the data

that allowed them to create 'psychographic' profiles for tens of millions of voters.

Just like demographics, psychographics splits people up into groups. But instead of basing the groupings on characteristics such as age and gender, psychographic data is concerned with your personality. The theory is that by knowing your psychological quirks, they can show you adverts that you're more likely to respond to.

Creating an ad using psychographic data isn't illegal, but Cambridge Analytica allegedly obtained Facebook data from a third-party app developer without most of the Facebook users' explicit consent. It is thought that just under 300,000 people installed 'This Is Your Digital Life', yet the data of 87 million people was collected.

Cambridge Analytica worked for Donald Trump's campaign during the 2016 US

We have a responsibility
to protect your information.
If we can't, we don't deserve it.

You may have heard about a quiz app built by a university researcher that leaked Facebook data of millions of people in 2014. This was a breach of trust, and I'm sorry we didn't do more at the time. We're now taking steps to make sure this doesn't happen again.

We've already stopped apps like this from getting so much information. Now we're limiting the data apps get when you sign in using Facebook.

We're also investigating every single app that had access to large amounts of data before we fixed this. We expect there are others. And when we find them, we will ban them and tell everyone affected.

Finally, we'll remind you which apps you've given access to your information – so you can shut off the ones you don't want anymore.

Thank you for believing in this community. I promise to do better.

Mark Zuckerberg





ABOVE: Over the course of two days in early April, Facebook CEO Mark Zuckerberg testified about the social network at US Congress

presidential election, but the consulting firm denies using the Facebook data for the services it provided. Nevertheless, on Friday 16 March, Facebook suspended Cambridge Analytica and its parent company Strategic Communications Laboratories from the social network.

On 6 April another data-driven marketing company, AggregateIQ, was suspended from Facebook after it was reported to be affiliated with Cambridge Analytica. AggregateIQ, which is based in Canada, worked on the Leave campaign during the EU referendum in the UK but denies it has links to Cambridge Analytica.

At the time of going to print, Facebook CEO and chairman Mark Zuckerberg had appeared before Congress to explain how the data breaches happened, and to answer further questions about the inner workings of Facebook.

EXPLOITING YOUR QUIRKS

There's research showing that targeting adverts to people's personality traits does work. A 2017 study tailored online ads for cosmetics based on whether the researchers thought someone was

“COMPANIES
LOOK AT
YOUR PAST
ACTIONS IN
AN ATTEMPT
TO FIGURE
OUT WHAT
YOU MIGHT
BE RECEPTIVE
TO DOING IN
THE FUTURE”

extroverted or introverted. For extroverts the ad read “Dance like nobody’s watching” but introverts saw an ad saying “Beauty doesn’t have to shout”. These carefully crafted ads reached 3.5 million people on Facebook. It paid off: people were 40 per cent more likely to click on the ad and 50 per cent more likely to buy something when the ad they were shown matched their personality. “It’s very likely that psychological targeting works,” Dr Sandra Matz, lead author of the study, told *BBC Focus*. “But we don’t know how effective it is in comparison to other targeting methods.”

Targeted advertising isn’t new. The gold standard is behavioural targeting, where companies look at your past actions in an attempt to figure out what you might be receptive to doing in the future. “If someone has expressed an interest in travelling in the past, you know they might be a good candidate to receive adverts for travel,” Matz said.

Psychographic targeting is an extension of this, but instead of looking at individual behaviours, companies look at a range of behaviours and label them as a personality trait. But there’s not enough evidence yet to say if that extra step is worthwhile. In fact, psychographic targeting could have more room for error as it relies on translating your digital footprint into a personality type. ●

● While Facebook doesn't allow advertisers to target people based on personality, it does let advertisers target people based on things that they have 'Liked'. Luckily for companies that want to try psychographic targeting, there's research showing that your Facebook Likes can be revealing.

In 2007, Dr David Stillwell, deputy director of the Psychometrics Centre at the University of Cambridge, created a personality quiz app that pre-dated Kogan's, but he only collected data for academic research purposes. It assessed your psychology based on a selection of personality traits known as the 'Big Five': openness, conscientiousness, extraversion, agreeableness and neuroticism. And it hoovered up all your Facebook Likes data to compare it with the results of the quiz. Using these two sets of data,

Stillwell and his team figured out which Likes predict which traits. For example, liking the TV show *Stargate* suggested introversion, while liking philosophy meant you probably scored highly for openness. In 2013, Stillwell's team published a paper showing that Facebook Likes could reveal your sexual orientation, ethnicity and other personal information.

Stillwell told *BBC Focus* that he thinks the research on psychographic targeting should translate to the political realm. "I think people probably make political decisions in a way that is not so dissimilar to the way they make consumer decisions," he said. Matz agrees: "Everything we know from persuasion literature is that it usually works across contexts."

But Dr Tessa West, a psychologist at New York University, isn't sure that getting people to vote

"EVEN THINGS
LIKE RAIN ON
POLLING DAY
ARE KNOWN
TO REDUCE
TURNOUT"

The browser plug-in Who Targets Me monitors the adverts that people are exposed to





Former Cambridge Analytica employee Christopher Wylie was the whistleblower who exposed Cambridge Analytica's possession of personal data

at all, let alone change their vote, would be as easy as getting them to buy cosmetics. “Getting people to vote is one of the toughest things social psychologists have yet to crack,” she said. She points out that even things like rain on polling day are known to reduce the turnout.

LIKE FOR LIKE

As for tailoring messages to persuade people to change their minds, when it comes to politics, people prefer an echo chamber. “The number one driver of what kind of information is going to be persuasive to someone is something that’s consistent with their ideology,” said West. “It’s very hard to flip people.”

Either way, Stillwell doesn’t think that Cambridge Analytica’s technology is influencing elections just yet. “I don’t think this affected the [2016 US presidential] election, but I think it could affect future elections as it becomes more sophisticated,” he said.

That’s not to say we have nothing to be worried about at the moment. Research has shown that you can predict people’s personalities from all sorts of data. “Tweets, emails, web searches, bank records – all sorts of companies could predict people’s personalities from the data they’ve got,” said Stillwell. “This isn’t just about Cambridge Analytica and Facebook Likes.”

Kelly Oakes is a science writer who was previously the science editor at BuzzFeed.

DISCOVER MORE



Listen to an interview about nudge theory, a tool used in behavioural science to subtly influence decisions, on the Science Focus podcast. Visit [sciencefocus.com/sciencefocuspodcast](https://www.sciencefocus.com/sciencefocuspodcast) or subscribe on iTunes, Acast, Stitcher or your favourite podcast app.

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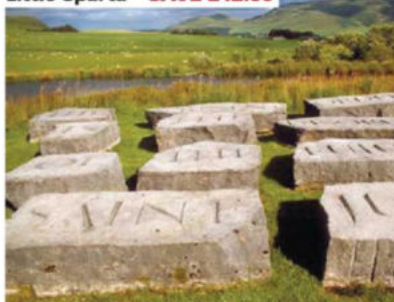
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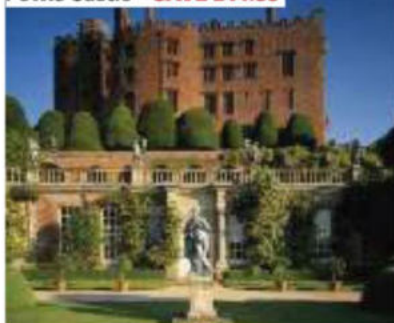
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MAY 2018

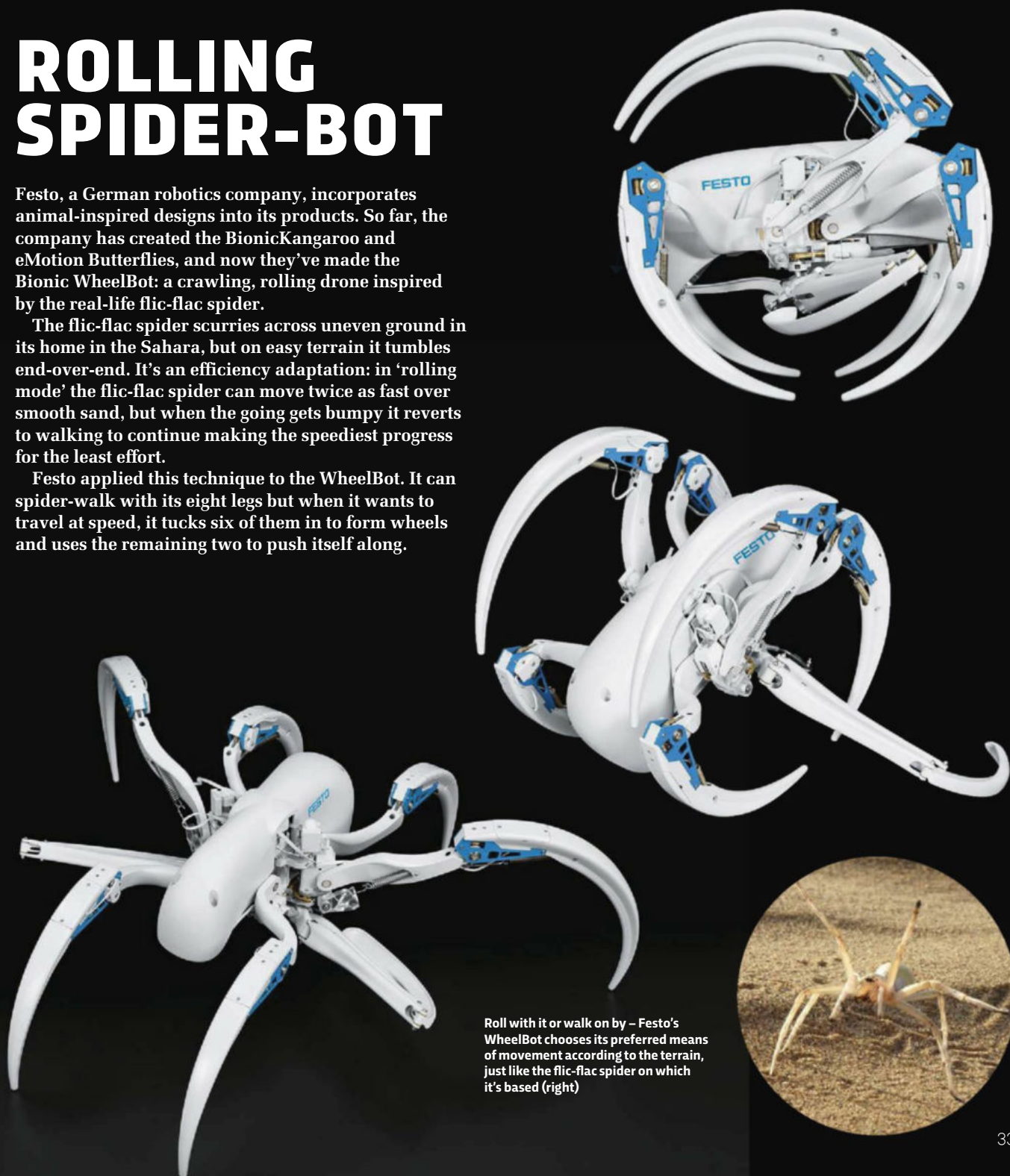
EDITED BY HELEN GLENNY

ROLLING SPIDER-BOT

Festo, a German robotics company, incorporates animal-inspired designs into its products. So far, the company has created the BionicKangaroo and eMotion Butterflies, and now they've made the Bionic WheelBot: a crawling, rolling drone inspired by the real-life flic-flac spider.

The flic-flac spider scurries across uneven ground in its home in the Sahara, but on easy terrain it tumbles end-over-end. It's an efficiency adaptation: in 'rolling mode' the flic-flac spider can move twice as fast over smooth sand, but when the going gets bumpy it reverts to walking to continue making the speediest progress for the least effort.

Festo applied this technique to the WheelBot. It can spider-walk with its eight legs but when it wants to travel at speed, it tucks six of them in to form wheels and uses the remaining two to push itself along.



Roll with it or walk on by – Festo's WheelBot chooses its preferred means of movement according to the terrain, just like the flic-flac spider on which it's based (right)

1



2



3



4



5



6



WANTED

1

ALL DAY INSPIRATION

Imagine how productive you'd be with a stream of inspirational messages from the likes of Salvador Dali, Walt Whitman and Mark Twain. Quotes Watch sends motivational words to your wrist as often as you like to spur you on.

Quotes Watch

€99 (£86 approx), bit.ly/quotes_watch

2

SILENT NIGHT

Light sleepers rejoice! QuietOn Sleep noise-cancelling earphones are designed to block out the specific frequencies of snoring. They're still a prototype so the look might change, but they'll stay small and comfortable.

QuietOn Sleep

\$149 (£105 approx), bit.ly/quietonsleep

3

LOCK UP, LOOK SHARP

Tapplock One turns your garden shed or your gym locker into a secure fortress. Only your fingerprint will unlock it. But if it's too cold to take off your gloves, you can tap in a Morse code combination instead.

Tapplock One

\$99 (£70 approx), tapplock.com

4

GAME CHANGER

PlayTable is the first blockchain game console. It works with physical pieces, cards and dice, and is designed to work as an interactive board game, and uses blockchain tech to keep track of moves and 'level up' your pieces.

PlayTable

\$599 (£429 approx), playtable.com

5

FITBIT FOR KIDS

Fitbit's contribution to the fight against childhood obesity is the Fitbit Ace. It tracks steps, active minutes and sleep, and rewards kids with messages and virtual trophies when they hit daily goals or win step challenges.

Fitbit Ace

£79.99, fitbit.com

6

LOW-PRO

GoPro's updated its entry-level offering, integrating a two-inch touchscreen and waterproof body to what will be its cheapest model. There's no 4K or slow motion, but for half the price of its high-end model, it's worth it.

GoPro Hero

£199.99, gopro.com

CRUZ THE COAST

Legendary surfer Jeff Clark has collaborated with Vintage Electric on the Jeff Clark Signature Cruz – an electric bike that'll make you feel like you're cruising down the sunny Californian coast, even if you're just battling Tuesday morning traffic.

Powered by a 52V battery, Vintage Electric claims its direct-drive hub motor is completely silent and takes only two hours to recharge. It has a 56km (35-mile) range, and a top speed (in 'race mode' – private-property riding only) of 57km/h (36mph). The Signature Cruz also has Shimano hydraulic

disc brakes with a regenerative function that pumps power back into the battery when you brake.

The Signature Cruz's surf vibe is all in the accessories. The handlebars, seat and removable surfboard rack are wrapped in Brooks leather. The rear rack is mounted with insulated panniers that double as cooler bags and there's even a bottle opener attached. Front and rear LED lights mean you can set out before dawn and return after dusk.

Vintage Electric Jeff Clark Signature Cruz

\$5,995 (approx. £4,250), vintageelectricbikes.com





The trees have ears... well, smartphones that enable them to listen for the sounds of illegal logging

CONSERVATION

MACHINE LEARNING JOINS THE HUNT FOR ILLEGAL LOGGERS

Old smartphones have been given a new life inside trees in the rainforest, where they're listening for sounds of illegal logging, thanks to non-profit organisation Rainforest Connection. And they're getting better at it every day, by way of a machine learning framework called TensorFlow.

Rainforest Connection's 'guardian devices' (solar-powered, modified smartphones) send audio to cloud-based servers over local cell networks. Each guardian device can pick up chainsaw sounds from up to a mile away. Once the data is in the cloud, Rainforest Connection uses TensorFlow, an open-source platform created by Google, to analyse the audio in real-time for sounds of chainsaws, logging

trucks and other illegal activity. When logging activity is detected, Rainforest Connection's devices alert local park rangers.

As the phones gather more data TensorFlow algorithms tune its software to detect suspicious sounds more accurately. Any improvement in the detection algorithm can lead to more trees being protected, a step forward in the fight against to preserve these ecosystems.

Every year the world loses an area of rainforest half the size of England, and it's estimated that 50 to 90 per cent of that loss is through illegal logging. As well as being harmful to wildlife, it's a major contributor to climate change.



Orion Span is aiming for a chic, spacious interior: "Ikea-ish, but much higher end"

SPACE

SPACE HOLIDAYS TO START IN 2022

If you're one to plan ahead, you might want to consider the Aurora Station for your summer holiday in 2022. Your trip will start in Cape Canaveral, Florida, where you'll be launched 320km (200 miles) above the Earth's surface to board the Aurora Station for a 12-day stay.

Orion Span, a Californian space technology start-up, is running the station, which they describe as the world's first luxury space hotel. It's being developed by the company's team of space industry veterans, who have 140 years of space experience between them.

It's not a trip for budget travellers: the holiday will set you back a whopping \$9.5m per person (£6.7m approximately) but you only need put down an \$80,000 deposit to secure a spot. That's much cheaper than

previous holidays to space – to date, eight people have taken trips into orbit as tourists, each paying an estimated \$20m to \$40m (£14.2m to £28.4m).

Planning for the trip is essential. Holidaymakers will need to complete three months of training before the trip, most of which can be done online. The four guests on each trip will be joined by two crew members, both of whom are ex-astronauts.

Once you're in space, you'll be able to float around in zero gravity and take part in experiments, such as trying to grow food in orbit. The Aurora station will complete an orbit of Earth every 90 minutes, so you'll have hundreds of opportunities to gaze down on your favourite places – you can post any snaps you take to Instagram via the station's high-speed internet connection.



Length: 13 metres

Diameter: 4.2 metres

TYLER ROEMER, ORION SPACE, KAIST

TECHNOLOGY

FRIENDLY ROBOT FIGHTS LONELINESS



Scientists from research institutes in Korea designed Fribo, a cute robot for your home, to foster interaction between young people living alone. Revealed at an international conference on human-robot interaction in March, Fribo listens for activity in your house and reports it to your friends in an effort to encourage chat.

Fribo recognises activities such as someone opening a door or turning on a light (it doesn't record voices) and shares those updates with your network, prompting friends to reach out to each other by texting or calling. Users can also respond to an update by clapping near their Fribo, which can send a message back, such as 'welcome home' to someone arriving to an empty flat.

When Fribo was tested in Korea, one user said that "it's like sharing daily-life activities with friends."



REALITY CHECK

Virtual reality (VR) is closing in on actual reality, and the HTC Vive Pro is at the head of the pack. **Helen Glenny** finds out if this is the model that could finally let us enjoy total immersion...

Sitting on the floor of an infinitely proportioned, dark warehouse, I used a thick brush to paint the space in front of me in forest green. Experimenting, I spattered yellow and orange spots to my left, and turned around to create an electric fence of neon grey lines. Looking around at the garish cocoon I'd painted myself into, a feeling of claustrophobia started to creep in. Filled with the need to return to the real world, I dropped my controllers and pulled off my headset.

I was testing the new HTC Vive Pro headset, which gives us virtual reality in higher resolution, with streamlined audio and a headset whose weight is easier to ignore. It's aimed at the most dedicated gamers and designers, since it's expensive and takes a long time to set up (sensors need to be placed around the room to track your movement). But we've been following VR from its infancy and are eager to see if it's finally shaken off its nauseating, clunky roots, to become the wholly immersive experience it always promised.

IMMERSION PLUS

Put on the headset and the Vive Pro's selling point is immediately noticeable: super-fine resolution that reduces, if not erases completely, any clues that you're in a VR environment. Say goodbye to jagged edges, pixelated backgrounds and boxy objects, and hello to wacky, weird, but visually plausible new worlds.

We started our test in *Tilt Brush*, a Google-built drawing program that allows you to paint in 3D, with brushes that come in neon, duct tape, snowflakes and paint splatters, along with the usual. To see what real artists can do, I loaded a pre-painted creation. Up popped an inch-high ballerina in a deep forest, her skirt a detailed layering of hundreds of tiny brushstrokes, each

one a different shade of green or orange. This detail is possible because of the Vive Pro's dual OLED displays, which now sit at a resolution of 1400 x 1600 per eye, compared to 1080 x 1200 in the original Vive. If you know your resolution maths, that's a 78 per cent increase. In practice, it feels like jumping from standard to HDTV. But in VR, when the screen is just in front of your face, that shift in resolution makes a much bigger difference.

Built-in noise-cancelling headphones add good-quality audio (immersed in VR-world, just the sound of my brush dragging across an invisible canvas created the illusion of friction) and are easy to flip up when you want some awareness of what's going on around you. High-spec gaming headphones might give better audio quality (you can remove the built-in ones if that's your preference), but the attached headphones reduce hassle.

ON VIRTUAL TIME

With the Vive Pro, immersion is comfortable for longer periods of time. That's partly due to the resolution quality, but Vive claims the easy-to-use headset and improved ergonomics also play a role. After *Tilt Brush*, I tested those claims in *SUPERHOT VR*, a combat game where you punch, shoot, and throw ninja stars. When you stay still, time slows down; start moving and time (and your attackers) speed up.

After an hour of throwing uppercuts and dodging bullets *Matrix*-style, the headset was still firmly and comfortably in place, even surviving a few dives to the ground. But my best effort in the game was thwarted when the headset's cable got wrapped around my leg, and, distracted, I took a bullet to the shoulder. The thick cable that trails from the side of the headset is still necessary, which is a shame considering the games and

graphics have progressed to a point where moving quickly is the norm. Thankfully, HTC has announced that later in the year they'll be untethering the headset with a wireless adapter, for an additional cost.

Compared to the original Vive and the Oculus Rift, the headset is more balanced, which means less pressure on your nose and neck. The overhead strap is thicker and softer, and there's more padding at each contact point. I still wouldn't want to wear the Vive Pro for hours on end, though, as after a long session it started to feel weighty, and I felt dizzy and unable to focus. There is hope, however, as HTC claims that VR tolerance builds with regular use.

THE DOWNSIDE

The Vive Pro is certainly the most impressive VR headset on the market, and its price tag reflects that. The headset alone retails at £799, which doesn't include controllers, base stations (add those for an additional £249), or the high-powered gaming PC you'll need to run it. We used the Acer Predator Triton 700, which had enough firepower to run the games flawlessly, even if we had to add a mouse to bypass the frustrating touchpad.

With an involved setup (our experience involved multiple new programs, driver downloads and a ton of hits on the 'troubleshooting' link), room-scale VR like the Vive Pro is an investment for those who are going to install their system permanently and use it often. For anyone who's just dabbling in VR, the Oculus Rift (£399) and original Vive (£499) are solid options at a more palatable price.



MAIN IMAGE: The highly addictive *Tiltbrush* in action

LEFT: Acer's Predator Triton 700 gaming PC had the required grunt to run the VR games

BELOW: The Vive Pro headset is pretty comfy

VERDICT

The HTC Vive Pro's resolution jump produces the first VR experiences that are so engrossing that you forget you're just flailing about in your lounge. The cost can only be justified by the most dedicated gamers or designers, but if that's you, it's worth emptying your wallet for. **8/10**

WHAT'S NEXT IN VR?



PIMAX 8K

Pimax showed off its latest prototype at CES 2018: a headset with 8K resolution that puts the Vive Pro's graphics to shame. Reports say it's too cumbersome and impractical to catch on, yet the visuals are stunning.



MAGIC LEAP ONE

Not much is known about Magic Leap's mixed reality headset, but its technology is said to trick your brain into seeing things that aren't there through use of artificial light fields. Look out for it later in 2018.



MICROSOFT HOLOLENS

The HoloLens is an augmented reality headset (you can see the real world through the glasses, but with superimposed graphics). While its first edition is on sale, a smaller, cheaper iteration is expected in 2019.



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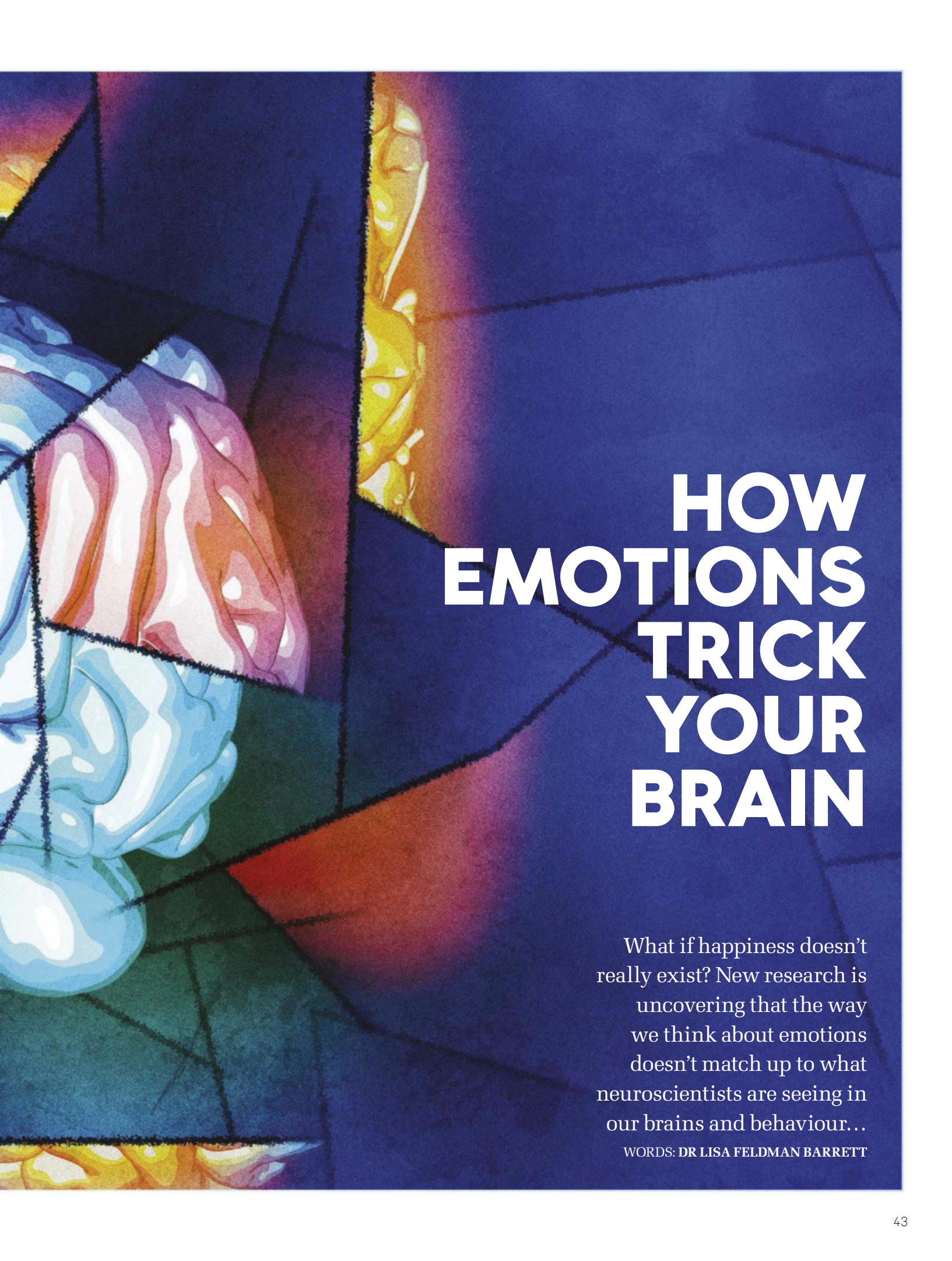
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ILLUSTRATION: MAGIC TORCH

The background is a dark blue field with a network of thin, dark, hand-drawn lines. On the left side, there is a stylized, colorful silhouette of a human head in profile, facing left. The silhouette is composed of various shades of blue, purple, pink, and orange, with some areas appearing more saturated than others. The overall effect is artistic and somewhat abstract, suggesting themes of psychology, neuroscience, or emotion.

HOW EMOTIONS TRICK YOUR BRAIN

What if happiness doesn't really exist? New research is uncovering that the way we think about emotions doesn't match up to what neuroscientists are seeing in our brains and behaviour...

WORDS: DR LISA FELDMAN BARRETT

How do emotions work? This might seem like an odd question since we all experience emotions every day: happiness at seeing an old friend, sadness while watching a tragic film, fear of losing the ones

we love. Emotions seem automatic. Your heart skips a beat, your nerves do a little dance, your face moves in familiar ways, and you are carried away by the experience. Nevertheless, from a scientific standpoint, what are emotions really?

For centuries, famous thinkers like Plato, Aristotle, Darwin and Freud, as well as countless other scientists, have tried to explain emotion using common sense. Emotions feel natural and uncontrollable, the reasoning went, so they surely must be built into us from birth. In recent years, however, the field of neuroscience – the study of how the human brain creates the human mind – has surged. With this interest has come intense research and renewed debate on the nature of emotions.

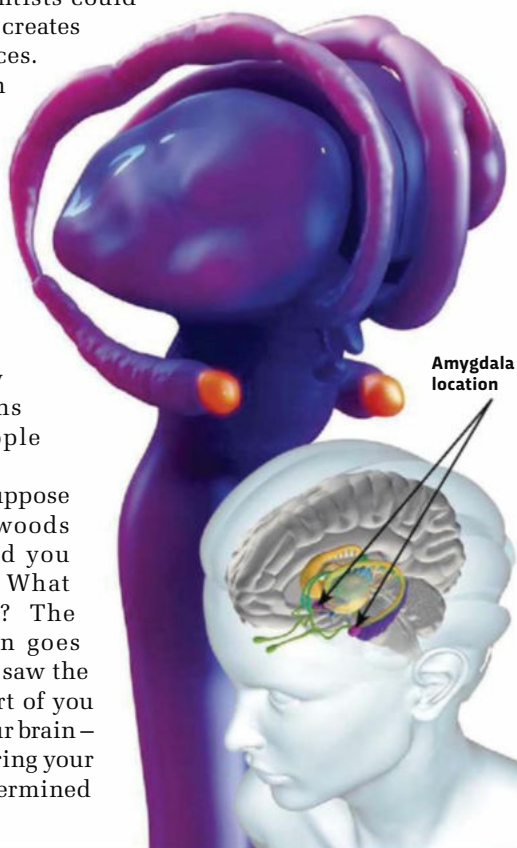
A few decades ago, scientists could only guess how the brain creates our emotional experiences.

Now, though, we can use brain-imaging to harmlessly peer inside a head. This allows us to observe neural activity, moment by moment, inside living people. And when it comes to emotion, what we see in those brains seems to defy common sense. Emotions are not what most people think they are.

Here's what I mean. Suppose you're walking in the woods and you see a bear, and you instantly feel afraid. What happened inside you? The traditional explanation goes like this. As soon as you saw the bear, some dedicated part of you – like a 'fear circuit' in your brain – sprang into action, triggering your body to react in a predetermined

"Ifaluk people have an emotion, 'fago', that can mean love, empathy, pity, sadness, or compassion"

BELOW: The amygdala is involved in thinking, memory, empathy and emotion. It is seen here as two orange structures, connected to the hippocampus



way. Your heart raced, your blood pressure soared, and your face formed an expression of fear that's said to be universal across all human cultures. In this classical view of emotion, the firing fear circuit, the bodily changes, and the facial expression supposedly form a distinct, detectable 'fingerprint' that distinguishes fear from all other emotions. That fingerprint was presumably passed down to humans through evolution, along with fingerprints for other emotions.

CHANGING TIMES

As compelling and intuitive as the classical view may be, it can't possibly be correct. Scientists have been searching for emotion fingerprints in the face, body and brain for over 100 years without success. Occasionally, you'll see a news story that scientists have found fingerprints of happiness, sadness, anger, fear, or other emotions in humans or other animals, but when other scientists retest those claims, they invariably don't hold up. For example, for many years, scientists believed that the brain's 'fear circuit' was a region called the amygdala. If you google 'amygdala fear' you can still find thousands of articles that make this claim. Nevertheless, it's not true. We now know definitively that some people who lack an amygdala can still feel fear. Not only that, but the amygdala is involved in dozens of other mental functions (such as thinking, memory, empathy and all other emotions), so it's clearly not a fear circuit. The same is true of every other brain area that has ever been claimed as the home of an emotion.

The main problem with the classical view of emotion is that emotional life has too much variety to be shoehorned into a bunch of universal fingerprints. Do your eyes widen every time you're afraid? Do you always gasp? Of course not. People who feel fear might scream, cry, laugh, close their eyes, clench their fists, wave their arms, strike out, faint, or even stand motionless. We also smile only about 12 per cent of the time when we're happy, according to a recent statistical analysis of many studies, and scowl 28 per cent of the time when



angry. Another study on babies showed that their facial movements are pretty much indistinguishable in fear and anger. No emotion has a single fingerprint in the body. Instead, variety is the norm.

Not only that, but different cultures have different emotions. For example, the German language contains three distinct angers with different meanings, while Russian has two and Mandarin has five. Plenty of cultures have emotions that don't translate into English. The Ifaluk people of Micronesia, for example, have an emotion, 'fago', that can mean love, empathy, pity, sadness, or compassion, depending on context. Even more intriguing, some cultures don't have a unified concept of 'emotion' for the events that Westerners experience as emotional. One example comes from the Himba people of Namibia. When you see somebody laughing, you might perceive that they're happy or amused, but the Himba would

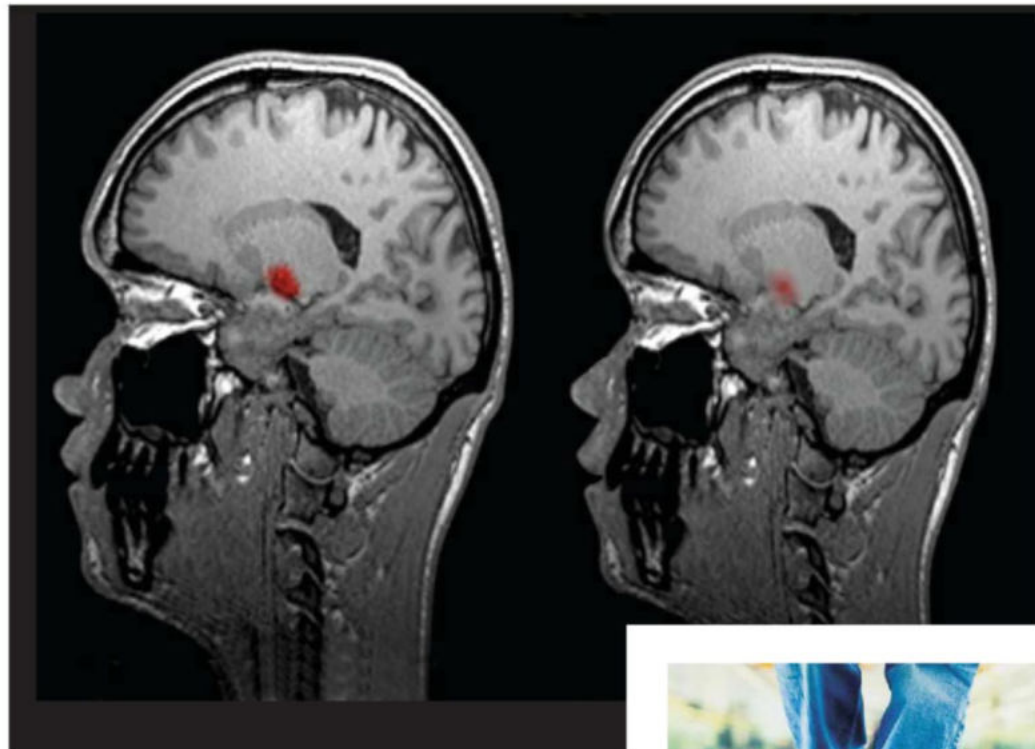
ABOVE: The Himba people do not associate laughter with an emotion – they simply perceive the person as laughing

simply perceive the person is laughing. They don't perceive laughter in mental terms. Throughout the world, the sheer variety of emotional life is vast – too vast to be explained by the classical view.

SO, HOW ARE EMOTIONS MADE?

The answer of how emotions are made flies in the face of common sense, because the human brain is a master of deception. Like a magician, it creates incredible experiences as diverse as joy, envy, curiosity and wrath without revealing how it does so. But thanks to recent advances in brain imaging, which allows scientists to observe a living brain as it thinks, feels, and perceives its surroundings, we now have a pretty good idea of the brain's secret technique for making emotion.

Your brain's most important job is keeping your body alive. To accomplish this, it devotes most of its time to predicting what will happen next, so ●



ABOVE: Brain scans show regions of increased activity, which allows scientists to improve their understanding of emotions. Here, the subjects (male on the left, female on the right) are experiencing jealousy, and the hypothalamus is glowing red

RIGHT: Your brain makes predictions based on past experiences. But it can get it wrong, which is why you may stumble when stepping off a moving walkway. The same can happen with your emotions

• your body can be ready for any contingency. Studies show that your brain spends 60 to 80 per cent of its energy on prediction. In every moment, your brain issues thousands of predictions at a time, based on past experience, and the ones that win are (usually) the ones that fit the situation in the next moment. When you walk, for example, each time you lift your foot to take the next step, your brain anticipates how your foot will land. If your brain gets this wrong, you might trip. If you've ever been in an airport on a moving walkway, and have stumbled as you stepped off (or the last step just feels weird), you know how prediction error feels. Your brain also makes predictions about other people in the world. Studies show that when you meet strangers, you like and trust them more when their facial movements (like smiles or scowls) match your brain's guesses. Remarkably, you even consciously see their face more quickly!

Along with predictions about the world, your brain also makes them about your body so you stay alive and healthy. It forecasts when your heart should speed up or slow down, when your blood pressure should rise and fall, when your breathing should deepen, and when you need more salt, sugar, water or hormones, and attempts to meet those needs before they arise. It's like running a budget for your body, but instead of money, the currency is biological.

This budgeting process continues through your entire life, and most of the time, you aren't aware of it. But it produces something you know well: your mood. Somehow, through a mysterious

process that nobody understands, physical movements inside your body become mental. You feel generally pleasant, unpleasant, or anywhere in between. You feel calm or agitated. Your mood is like a barometer for the health of your body. It's with you every moment of your life, though much of the time it's in the background and you don't notice it.

This same process produces your emotions completely outside your awareness. Let's go back to our 'bear in the woods' example. When you're walking in the woods, your brain issues thousands of predictions in every moment, based on past experience. It anticipates each step, the crunch of the dry leaves underfoot, and the look of the greenery above you. It forecasts the heart rate and breathing that you'll need to keep up the pace. Your brain even issues

predictions about animals appropriate to the setting, such as bears, and prepares your body to deal with them. It sends signals to your heart to beat faster, your lungs to breathe deeper, and so on, and prepares your body to run. At the same time, your brain guesses how you will feel in a moment from now when you start running and produces an agitated mood. This entire collection of predictions comes from your past experiences of fear. So, if an actual bear shows up in the next moment, you're already starting to run and experiencing fear. That's why fear feels so automatic in that situation, like a reflex. Your brain explains your body's sensations and launches your movements before you're consciously aware.

MORE THAN A FEELING

But what if there's no bear? That's a prediction error, and you'll be left with an agitated feeling with no apparent cause. If you've ever walked in the woods at night and have suddenly startled for no apparent reason, you've experienced this. There's even a curious third possibility that there's no bear present, but you see a bear anyway, for a moment. You've probably experienced this too. Have you ever seen a person that you thought you knew, but then realised it's a stranger? Same thing. Your



“When walking in the woods, your brain issues thousands of predictions in every moment, based on past experience. So, if a bear shows up, you’re already starting to run and experiencing fear”

brain predicted someone you know, based on past experience, and just for a second, you saw them.

In short, emotions are your brain’s best guesses for what your body’s sensations mean, based on your situation. When your face feels hot as a driver cuts you off in traffic, you might experience the heat as anger. If you feel the same hot face when you’re inches away from having your first kiss, you might experience it as excitement. Or if you feel the same sensation as you walk out of the sea and realise your swimming costume has fallen down, you might experience it as



Dictionary corner

When you take a look at some of the words used around the world to convey emotions, the traditional concepts of 'happy' and 'sad' start to look a little one-dimensional. Lisa Feldman Barrett's lab has started collecting these 'untranslatable' words to start a new kind of dictionary. Here are 10 of our favourites. You can find an interactive index of more these words at bit.ly/emotion_dictionary

Jayus. Indonesian / n. / gah-yoose.

A joke that is so unfunny (or told so badly) that you just have to laugh.

~

Lekker. Dutch / adj. / leh-ker.

Tasty (food); relaxed, comfortable; pleasurable; sexy.

~

Gezellig. Dutch / adj. / khe-zell-ikh.

Cosy, warm, intimate, enjoyable; often a shared experience (with close others).

~

Njuta. Swedish / v. / nyoo-ta.

To deeply enjoy, to profoundly appreciate.

~

Bēi xī jiāo jí. Chinese / n. /

bay-shee-jeeow-jee. Intermingled feelings of sadness and joy.

~

Fernweh. German / n. / fiern-vay.

Far/distant pain/woe. The 'call of faraway places'; homesickness for the unknown.

Age-otori. Japanese / n. / (archaic)

aa-gey oh-toh-ree. To look worse after a haircut; styling one's hair for a coming-of-age ceremony, with the contrary effect of making oneself look worse than before.

~

Mamihlapinatapai. Yaghan / n. /

ma-mey-la-pin-ought-ta-pay. A look shared by two people, each wishing that the other would initiate something that they both desire but which neither wants to begin.

~

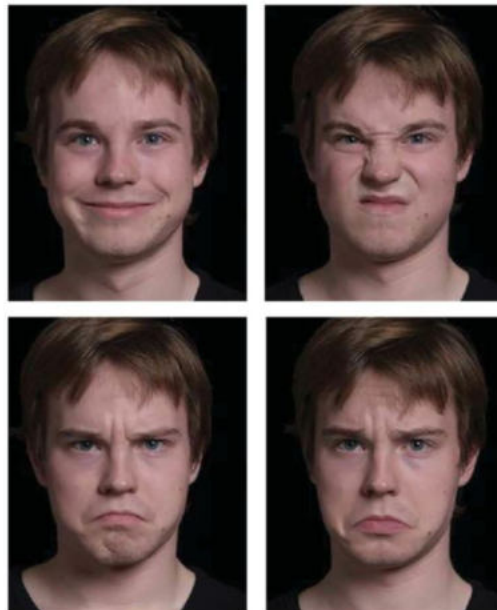
Shinrin-yoku. Japanese / n. / shee-n

ree-n yoh-koo. Taking in the forest atmosphere; forest bathing.

~

Daggfrisk. Swedish / n. / adj. /

daag-frisk. 'Dew fresh'; the kind of pure, clean feeling one might have from waking refreshed in the early morning at sunrise.



❖ embarrassment. Your brain makes meaning from the identical sensation in different ways, depending on context. That's how emotions are made. They are not built-in at birth. They are built in the moment.

In a sense, your emotions are constructed unconsciously from three ingredients: your body budget, your current situation, and predictions from past experience. If you modify any of these ingredients, you can take some control over your

emotions. I'm not saying this is easy, but it's possible.

Changing your body budget is the most straightforward of the three (but again, not easy). Eat healthily, get enough sleep, and exercise regularly, and your brain won't have to work as hard to keep your body budget in balance. That means your mood will be less negative and your brain will have fewer opportunities to create unpleasant emotions. You can change the second ingredient, your current situation, in a variety of ways. You can directly adjust your surroundings by moving to another location, like leaving the room or taking a walk. If that's not possible, you can indirectly change your surroundings by paying attention to other things around you – that is, being mindful.

The third ingredient, your predictions from past experience, is the toughest to alter because it's impossible to change your past. Yet if you take action in the present, you can modify your brain's predictions in the future, changing your future emotions. For example, in my family, we came up with an idea we call the 'emotional flu'. Have you ever felt wretched, like you're a horrible person, everybody hates you, and the world is going to end... but in fact, there's nothing actually wrong with your life? That's the emotional flu – you're having an unpleasant physical feeling, probably from a disrupted body budget, and your brain has

“Eat healthily, get enough sleep, and exercise regularly, and your brain won't have to work as hard to keep your body budget in balance”



ABOVE: Your brain has to constantly balance your body's budget to keep you healthy. If things get out of whack, it can impact your mood and create bad emotions. Eat healthily, get enough sleep and exercise regularly to give your brain a helping hand

ABOVE LEFT: Typical images used in the lab to test our perception of emotions

end... but in fact, there's nothing actually wrong with your life? That's the emotional flu – you're having an unpleasant physical feeling, probably from a disrupted body budget, and your brain has constructed all sorts of negative explanations that are deeply personal. To deal with these feelings, we took inspiration from the real flu. The influenza virus isn't personal – it simply takes up residence in your lungs. Likewise, we worked hard to view the wretchedness as purely physical, and to treat the symptoms with naps, walks, exercise, hugs, or whatever works. By repeatedly reframing the situation from personal to physical, my family and I changed our brains' future forecasts, making it easier to create the non-personal, non-judgmental, emotional flu. This was challenging to do at first, but it got easier with practice, and we've passed the idea along to friends who have also succeeded.

I'm not saying you can tweak a few predictions and cure a serious disorder like anxiety or depression, but it's possible to make tangible improvements in your life. That said, this way of thinking about emotion does have implications for understanding

mental illness. For hundreds of years, people have drawn a boundary between mental and physical illness. Cancer, heart disease and diabetes are seen as disorders of the body, while depression and anxiety are often viewed as ailments of the mind. But we now know that your brain constantly regulates your body budget, and when the budget's in the red, you feel bad. This suggests that problems with metabolism, traditionally associated with the body, are at the core of mood-related mental illnesses such as depression and anxiety. It also helps explain why physical illnesses like diabetes and heart disease have persistent mood symptoms. The boundary between the physical and the mental is more porous than previously thought, and understanding this is key to finding new pathways for prevention and treatment.

NEW OUTLOOK

This new view of emotion suggests something important about artificial intelligence. Is it possible to build a machine that can read people's emotions? Companies such as Facebook, Google, and Microsoft are betting that the answer is yes. They're spending millions of research dollars to detect emotion via software, by examining faces and bodies as their owners experience emotion. But emotions aren't readable in the face and body alone, because emotions have no fingerprints, and variety is the norm. This means these approaches are asking fundamentally the wrong questions. Tech companies must include more data about a person's context, and embrace the variation in real emotion life.

A tougher question is, can we build a computer that can feel emotion? Our new view of emotion offers an intriguing possibility. If emotion is constructed in part by regulating a body budget, then for a machine to experience emotion, it must have something like a body. Not necessarily a human-like body, but a set of complicated, interacting systems with energy needs that must be kept in balance. (No doubt some clever AI programmers can figure out a solution.) This will bring us closer to creating a machine that can feel and be empathetic. 🧠

Dr Lisa Feldman Barrett (@LFeldmanBarrett) is a psychologist and neuroscientist, and the author of *How Emotions Are Made: The Secret Life Of The Brain*.

DISCOVER MORE



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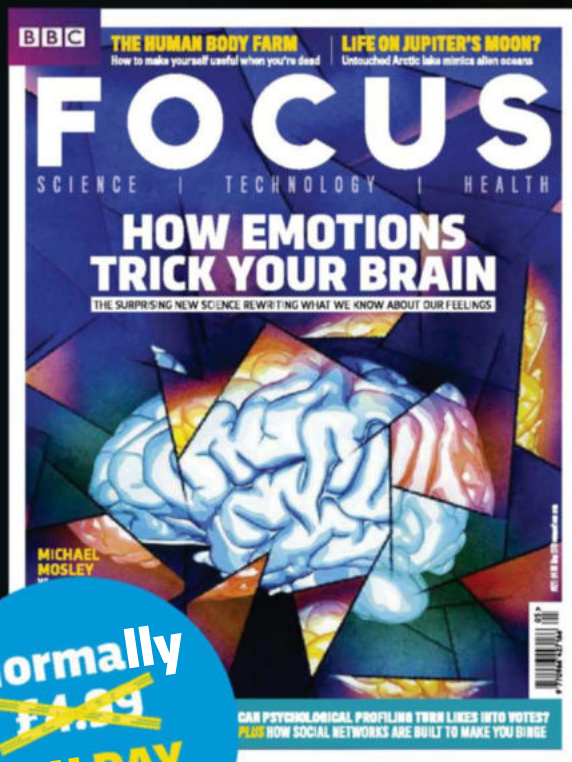
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DOWN ON THE BODY FARM.

Corpses can tell you a lot – if you know how to read them. And just like language, decomposition is dependent on location. Which is why some researchers say we need to start studying the dialect of decay in the UK

WORDS: ROB BANINO

Dr Anna Williams wants to watch you rot. It's nothing personal; it's for science, specifically the science of taphonomy, which is the study of decay and

fossilisation. By monitoring how corpses decompose, she hopes to increase our understanding of the subtleties of the process and improve the accuracy with which we can locate and identify dead people, and determine their time of death.

In order to do this, Williams, a forensic anthropologist at the University of Huddersfield, wants to establish a human taphonomy facility in the UK. There are already nine such facilities – colloquially known as 'body farms' – around the world: seven in the US, one in Australia and another in the Netherlands. So why

do we need one here?

"What we know about decomposition has come out of the American facilities," explains Williams. "Before the first one opened in 1981, we really didn't know very much about how bodies decompose in different conditions. The research that's been going on since then has really boosted our knowledge.

"And one of the things we've learned is that decomposition is incredibly dependent upon local conditions: the surrounding temperature, rainfall, humidity, soil type, ecology, insects, scavengers... it's all dependent on these variables. So, the information coming out of the existing facilities is very useful but it's not directly applicable to forensic cases in the UK."

In short, people in the UK don't decay in the same way as they do elsewhere. In fact, people don't always

Students excavate a corpse at the body farm at Texas State University

FBI PHOTO LIBRARY ILLUSTRATION: MICHAEL HADDAD

“TYPICALLY, WRAPPING A BODY WILL ACCELERATE DECOMPOSITION BUT IT ALSO DEPENDS ON IF IT’S BURIED OR NOT”

► decay the same way in the same country. And we wouldn’t know that if it wasn’t for the pioneering work of forensic anthropologist Dr William Bass.

LYING IN THE GRAVE

Bass founded the first human decomposition research facility at the University of Tennessee after recognising how misleading the decay process could be. The realisation came in 1977 after local police contacted Bass and asked him to examine some human remains they’d found in a disturbed grave. The corpse’s head was missing, but based on the remaining flesh and bones it was originally determined that the remains belonged to a white male in his mid-to-late 20s who’d been dead for about a year.

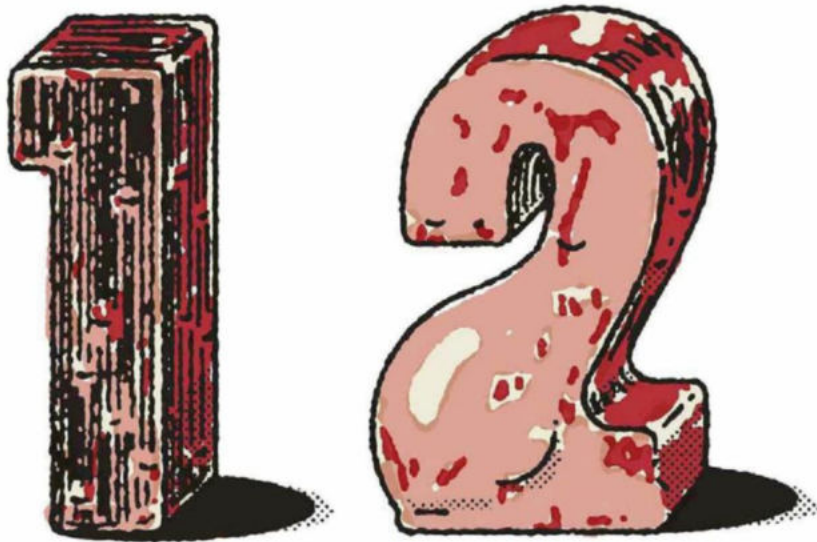
However, Bass’s examination revealed something astounding: the corpse was older than everyone thought. A lot older. It was actually the body of the Confederate soldier, Colonel William Shy, who’d been dead for over a century. The remains were so well preserved because they’d been embalmed and buried in an airtight coffin. What the police had found wasn’t a killer’s attempt to hide the body of a recent victim but the remains of a corpse that had been dug up by graverobbers. The confounding nature of Colonel Shy’s corpse led Bass to an epiphany: we needed a far better understanding of human decomposition and the factors that affect it. We needed to study it closely, and to do that we’d need decomposing bodies and somewhere to watch them fester.

That place ended up being a 2.5-acre (10,000m²) fenced-off wooded area in Knoxville, Tennessee, which today is known as the outdoor decomposition research facility of the University of Tennessee’s Forensic Anthropology Center. In the 37 years since it opened, Bass and his colleagues have scrutinised the decay of thousands of cadavers in various states: buried, unburied, whole, dismembered, hidden in car boots, wrapped in carpet and entombed in concrete. And the contribution they’ve made to our ability to locate and identify human remains, and



BREAKDOWN

Left unburied and uncovered, here’s what happens to a body...



The fresh stage can last a few days to a week. Rigor mortis initially sets in and cells break down as the lack of oxygen and nutrients prevents them from replenishing themselves.

When bacteria in the gut can no longer be kept in check, they start to reproduce and feed on the body. This produces gas that causes the abdomen to bloat.



more accurately infer their time of death, is unquantifiable.

DEATH FROM ABOVE

The progress made at Tennessee inspired other US universities, like Texas State University, to build on Bass's example. Dr Daniel Wescott is the current director of the Forensic Anthropology Center at Texas State (FACTS), which opened in 2008. "We have lots of graduate students researching different aspects of decomposition, such as what happens if you wrap a body in a specific material," he says. "Tarps and carpets tend to accelerate the rate of decomposition as they retain heat and moisture, and provide protection for the insects so that they feed a little faster. Typically, wrapping a body will accelerate the decomposition but it also depends on if it's buried or not."

They're also looking at ways to use drones to find bodies. Until now, searches for missing bodies have relied on manpower, specially trained sniffer dogs and ground-penetrating radar devices. But, as Wescott explains, FACTS is testing ways to locate corpses using drones. "In the early stages of decomposition you've got a lot of chemical reactions going on, you've got bacteria proliferating, you've got maggot activity... and all that generates heat. We can use infrared cameras on the drones to pick up that heat. 🕒



Students at Texas State University clean bones after the soft tissue has decomposed. The bones will be sent to the university's permanent skeletal collection



Gas building up increases pressure within the body, pushing fluids in between the layers of skin and causing the outer layers to slough off.



With no oxygen to bind to, haemoglobin in the blood binds to sulphur instead, filling the arteries and veins with a greenish-black substance. This gives the flesh an appearance known as 'marbling'.



Increasing pressure forces the body's fluids and liquefied organs out of any available orifice. Eyeballs can be dislodged and bodies have even been known to explode. ▶



Chemicals released by the body attract flies, which lay eggs in and around the orifices. Soon after, maggots hatch and begin feeding on the body's flesh and organs.



Other insects, such as beetles, are attracted to the body, as well as small birds looking to feed on them. Local scavenging animals will also appear to pick the flesh off the bones.



The final stage is skeletonisation, when the soft tissue is fully lost. Wind, rain, erosion and abrasion take over and the bones are disarticulated over the following months and years.

“A SKELETON’S NOT GOING TO GIVE OUT HEAT BUT WE CAN USE NEAR-INFRARED TO PICK UP A ‘CADAVER DECOMPOSITION ISLAND’”



At Texas State University, some corpses are kept inside cages to protect them from scavengers

“Later on, a skeleton’s not going to give out heat but we can use near-infrared photography to pick up what’s called a ‘cadaver decomposition island’. This is what you get when the fluids seep out of a decomposing body into the surrounding soil. We can pick up the areas of enriched soil because it reflects light differently.”

But as useful as this research is, no one can pretend the climate in the US is anything like that of the UK. “Environmental variables have a big influence on the rate at which a body decomposes. So, when you’re talking about trying to calculate how long somebody’s been dead, the basic principles that come out of Texas apply but the specific rate probably wouldn’t apply to Europe,” says Westcott. Which brings us back to Williams and the need for a human facility in the UK.

CEMETERIES AND SENSIBILITIES

Williams has already taken steps to advance the understanding of decomposition in the UK by opening an animal taphonomy facility in Cranfield University in 2011. But recent studies have shown that the pigs, rabbits, mice, sheep and deer used in such labs aren’t suitable analogues for humans because they have different gut bacteria, medical conditions, diets and lifestyles. To put it another way, pigs don’t smoke, get diabetes or overindulge on fast food, alcohol or drugs, all of which can affect the way a body breaks down. And if the information generated using animals isn’t comparable to humans, aside from the doubt it casts on any research, it can also be more easily undermined if it’s used in testimony during a trial.

Hence the need for a human facility in the UK. But in order to get one, Williams needs to raise the funding for it (to the tune of about £1m), find a suitable site and generate support from the UK’s universities, the Human Tissue Authority and the

public. All of which is a tricky proposition given the delicate nature of what Williams intends to study and people's perceptions of how she might study it. But there are ways to mitigate any offence an outdoor lab containing rotting corpses may cause. "One thing that we might do is try a staggered approach so that we start with a facility more like the one in Amsterdam, which is called a 'forensic cemetery' because the bodies are buried," she says. "You can't see the bodies as they're not on the surface and that's perhaps less objectionable, more readily acceptable."

In such a scenario, monitoring equipment and possibly even viewing windows would be installed underground to study the cadavers as they decompose. But it may actually be the perception of the public's attitude towards such a facility that's mistaken. A survey carried out by Williams suggests people are in favour of a human taphonomy facility in the UK, and she's already getting offers from people wishing to donate their bodies and has support from the Home Office. Were such a facility to eventually open here, aside from the research and training benefits it could provide, Williams believes it would also enable more people's dying wishes to be granted.

"At the moment lots of people want to donate their bodies to anatomy schools for teaching and dissection but often they're turned away because they have conditions that mean they're unsuitable. We think that at a taphonomy facility we'd turn away fewer people because it wouldn't matter so much what conditions they had or what state their body was in."

In an ideal world, Williams hopes that donors will not only be able to choose what sort of research their body is used for, and for how long, but also what happens to their remains afterwards – whether they're kept as part of osteological collections or returned to their families for burial or cremation.

"[If we get one in the UK] there'll be a lot of setting up at the beginning," says Williams. It will be probably months or even years before you get the first experiments underway because there's so much testing to do at the site... You've got to find out what everything is like – the soil type, the vegetation, the humidity, the temperature, the shade, even the number of worms, birds and snails – we need to know about all that before we put the bodies in."

Whatever happens, there's still a lot of work to be done, even if a UK facility does get the go-ahead. 🗣️

Rob Banino is a Bristol-based writer and editor, specialising in science, technology and cycling.

DISCOVER MORE



Watch a short BBC video about Australia's body farm at bit.ly/body_farm



Listen to an interview with Dr Anna Williams on the Science Focus podcast. Visit sciencefocus.com/

sciencefocuspodcast or subscribe on iTunes, Acast, Stitcher, or your favourite podcast app.

OTHER THINGS TO DO WHEN YOU'RE DEAD

Donating your body to medical science is one way to make yourself useful after death. But what if you want to do something that's not so 'run of the mill'?



CRASH CARS

Car manufacturers like to demonstrate the efficacy of their vehicles' safety features by showing you slow-motion video of dummies getting thrown about during a collision. What they're less keen to publicise is that they've probably put dead bodies through the same tests to see how the impacts affect their internal organs.



PUT ON A SHOW

Body Worlds exhibitions feature real corpses and organs that have been preserved through plastination, a technique invented by German doctor Gunther von Hagens. If you're willing to go on display after your bodily fluids and soluble fat have been replaced by liquid plastic, you could donate your body to the Institute for Plastination.



GROW A TREE

You can still make yourself useful after you've been cremated, depending on what happens to your ashes. Scattered on soil, they'll act as a general fertiliser but if you want something more specific you can have them added to a Bios Urn, a biodegradable container that's packed with soil and used for tree seed germination.



RELEASE A RECORD

An audio recording of your voice or music that held a special meaning for you is one way that loved ones can treasure your memory. If, however, you'd like the keepsake to bear slightly more of your physical presence you can get **andvinly.com** to press your ashes into the vinyl on which your voice and music is printed.

TRA

The secret ways social media is built to be addictive (and what you can do to fight back)

WORDS: CATHERINE PRICE

Ever looked up from your phone and wondered where the past 30 minutes have gone?

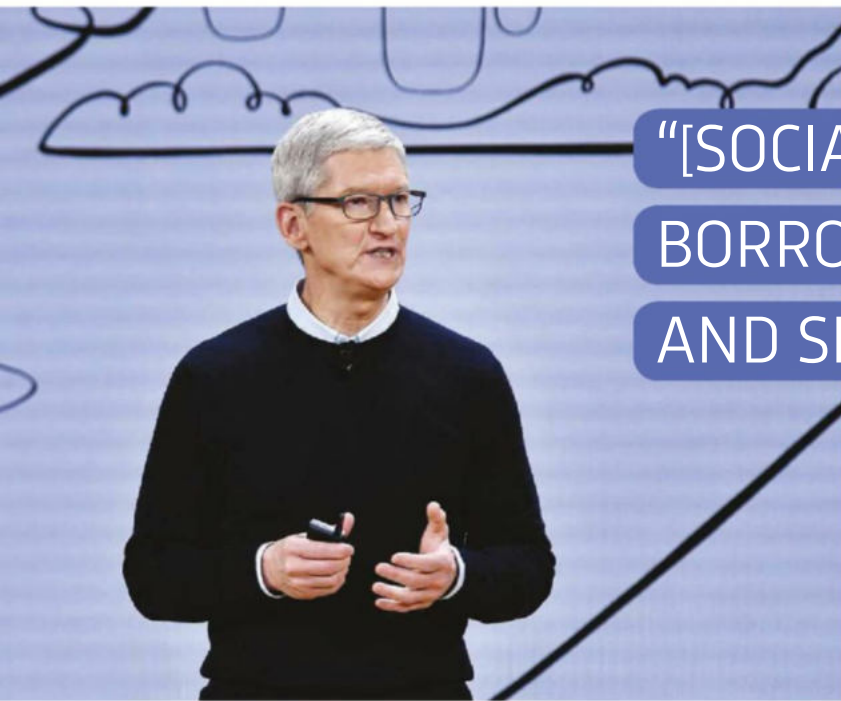
If so, you're certainly not alone. According to *Moment*, a time-tracking app with more than 4.8 million users, the average person spends nearly four hours on their phone every day. That's one-quarter of our waking lives, and much of that time is devoted to social media apps such as Facebook, Instagram and Snapchat.

But while we're busy burying our noses in our newsfeeds, a strange thing is going on in Silicon Valley: tech insiders have begun to speak out against some of the very products they helped to create.

"I feel tremendous guilt... I think we have created tools that are ▶







“[SOCIAL MEDIA’S] TRICKS ARE BORROWED FROM CASINOS AND SLOT MACHINES”

that I won't allow. I don't want them on a social network.”

So what do the social media executives know that we don't? And what tricks do they use to keep us coming back for more, and more... and more?

● ripping apart the social fabric of how society works,” said Chamath Palihapitiya, Facebook's former vice president for user growth, last November during a talk at Stanford University's Graduate School of Business. He added that he himself rarely uses Facebook, and that his children “aren't allowed to use that sh*t”.

Social media “literally changes your relationship with society, with each other,” said Sean Parker, the founding president of Facebook, at an event in Philadelphia around the same time. “It probably interferes with productivity in weird ways. God only knows what it's doing to our children's brains.” Meanwhile, Apple's chief executive Tim Cook has said that, when it comes to his nephew: “There are some things

THE PRICE OF A LIKE

First, we need to remember why social media companies would want to get us hooked in the first place. The market value of Facebook (which, it's worth noting, also owns the popular social media platforms Instagram and WhatsApp) surpassed \$500bn before the Cambridge Analytica row. But as anyone with an account knows, you don't have to pay to use Facebook. It says so right on their home page: “It's free and always will be.”

Those facts might sound contradictory, but they're not. Facebook is free to use because we are not the customers. Instead, *advertisers* are the customers, and our attention is what's being sold. Think about it: the more time you spend on a social media platform, the more opportunities there are for the platform to show

ABOVE LEFT: Apple CEO Tim Cook is not a fan of social media, and doesn't want his nephew to use it

BELOW: The Cambridge Analytica scandal has revealed how data from social media can be used without users' consent

RIGHT: Social media apps use similar tools to those employed by casinos to keep you scrolling through your feed



you ads. Every minute you spend on social media is a minute spent making money for someone else.

It's also a minute spent voluntarily providing data that can be collected and sold. As Antonio García Martínez, a former product manager at Facebook, writes in his memoir, *Chaos Monkeys*, the company is actually "the regulator of the biggest accumulation of personal data since DNA". As well as recording and analysing our activities on Facebook itself, the social media company also collects data on many of our other online activities, and it even buys information from data collection companies, such as Experian, about your offline life. This information can include – but is certainly not limited to – your income, your credit history, outstanding loans, your credit limits, and essentially any purchase you've ever made with a card.

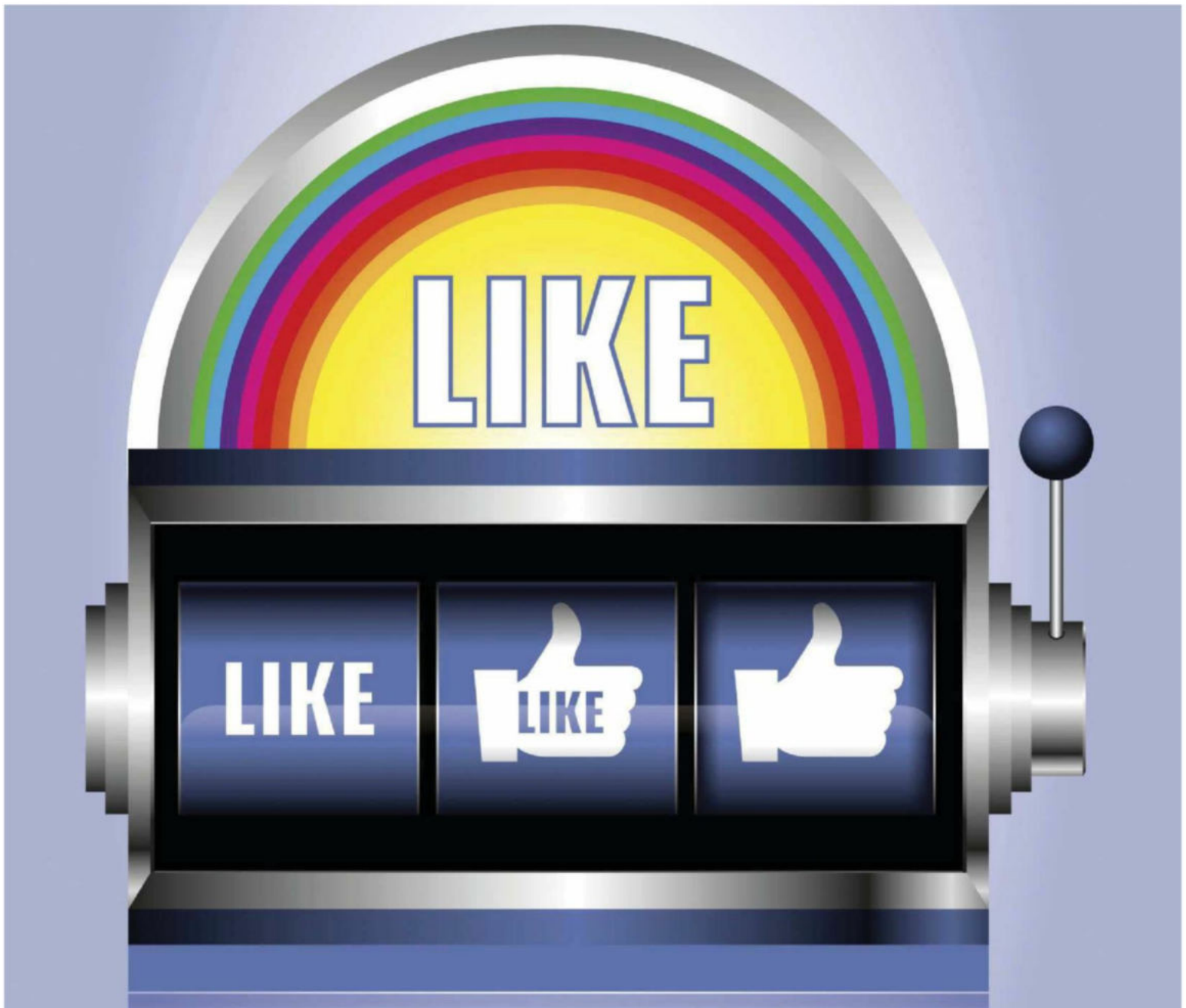
Facebook itself has shared numerous 'success stories' of how companies have used the social media giant's ability to slice, analyse and make predictions

off its data in order to target specific groups of customers. And then there are the recent headlines revealing how this data can be used for political ends, such as the scandal involving Cambridge Analytica, in which it's alleged that Facebook data was used (without users' or, supposedly, Facebook's knowledge) to deliver targeted adverts in support of Donald Trump (turn to p28 for more on this).

TRICKS OF THE TRADE

Regardless of whether you find this level of data collection creepy or simply capitalistic (or both), it explains why social media companies would want to capture our attention for as long and as frequently as possible: it's profitable. And to do this, they build features into their apps that manipulate our brain chemistry. These tricks are borrowed straight from casinos and slot machines, which are widely considered to be some of the most addictive machines ever invented. ●

GETTY X3



HOW TO FIGHT BACK

Worried that social media has you hooked?
Here are five tips to help you get the upper hand



ASSESS YOUR HABITS

Tracking apps such as *Moment* (iOS) and *RescueTime* (Android) calculate how much time you're spending on your devices each day, and what apps you use the most. If certain apps are problematic for you, use blockers such as the *Freedom* app to restrict your access when you want to get work done.



DELETE SOCIAL MEDIA APPS FROM YOUR PHONE

This doesn't mean you can't use social media if you really want to – just do so from the clunkier browser versions, ideally from your desktop – and make sure you log out afterwards. The point is to create a 'speed bump': a small obstacle that forces you to slow down so that if you decide to proceed, it's by choice.



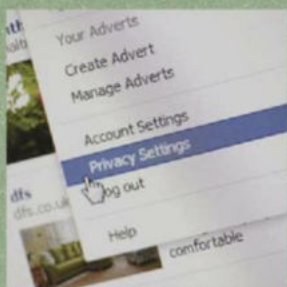
DOWNLOAD A 'DEMETRICATOR'

If you find yourself compulsively checking your Likes, try installing a social media 'demetricator' plug-in, so that instead of telling you how many people Like your post, it simply says, 'People Like this' (and similarly for comments and shares). Removing these metrics can help to reduce our impulse to 'score' and validate ourselves – one of the ways in which social media keeps us hooked.



GET MINDFUL

There's a simple mindfulness-based exercise you can do to help you become more aware of when and why you reach for your phone. When you pick up your phone (whether for social media or another purpose), simply ask yourself the three 'W's: "What am I checking for? Why am I doing so right now? What else could I do instead?"



ADJUST YOUR PRIVACY SETTINGS!

Some social media platforms allow you to control at least some of the data that they share, but these controls are often buried deep in their settings pages. Handily, non-profit newsroom ProPublica has created a plug-in for Chrome that allows you to see what Facebook's algorithms have concluded about you, and makes it easier to limit some of what's shared.

● Consider the 'pull-to-refresh' feature common to social media apps, where dragging the screen downwards prompts the screen to refresh. Not only is the action itself similar to pulling the lever on a slot machine, but it takes advantage of our attraction to unpredictability. Psychologists call this 'intermittent reinforcements' (and I call it 'the reason we date jerks'). Sometimes, when we check social media there's something exciting waiting for us (a 'reward'), sometimes there's not. It's the unpredictability that keeps us coming back.

Once you're plopped in front of a slot machine, the casino wants to keep you there – that's why most casinos are windowless with no clocks. Similarly, once you're trapped in a spiral of infinite scrolling, social media apps don't want you to look up. That's why their feeds are deliberately designed to be endless.

"Companies have systematically removed stopping cues – those brief moments, like reaching the bottom of a screen, that suggest you might want to move



on to something else,” says Adam Alter, psychologist at New York University and author of *Irresistible: The Rise of Addictive Technology And The Business Of Getting Us Hooked*. “Ethical video game developers introduce those cues to split their games into chapters, which liberates players to play the game in chunks rather than in long binge sessions. The same works for tech products. Where Facebook, Twitter and Instagram make their feeds bottomless, introducing natural end points would gently encourage users to move on to other activities.”

In other words, posts on your newsfeed *could* be presented as pages, just like Google search results. But then you would have to do something active (click through to the next page) in order to continue, which is exactly what app designers want to avoid.

“FACEBOOK, TWITTER AND INSTAGRAM MAKE THEIR FEEDS BOTTOMLESS”

BELOW: Welcome to
the worst dinner
party, ever



Video platforms like YouTube and Netflix use the same technique: they automatically start playing the next video or episode in your queue within seconds of the previous video's end. Sure, you could press stop, but wouldn't it be easier to just keep watching?

THE DOPAMINE EFFECT

Many of these attention-capturing tricks harness our brain's dopamine system. Dopamine is a neurotransmitter that is at the heart of all of our habits. “Dopamine is our brain's way of recording what's worth doing again,” explains Ramsay Brown, co-founder and chief operations officer at Boundless Mind, a tech start-up that uses our brain's dopamine system to nudge us toward behaviours that we actually *want* to engage in. “It's how we learn from our positive experiences.”

This is important from an evolutionary point of view – dopamine is released, for example, in response to eating or having sex. But the dopamine system of the human brain isn't able to distinguish between useful habits, such as feeding ourselves or paying the rent on time, and those that are destructive, such as smoking or doing drugs. When released in response to the wrong trigger, dopamine can reinforce habits to the point that they become addictions.

The question of whether we can be ‘addicted’ to our phones in the same way that we can be addicted to substances such as alcohol and drugs is controversial. But there's no denying that the dopamine system is involved in both. Every time we check our social media feeds and find something novel or exciting waiting for us (in other words, *every* time we check social media), our brains release ●



“SOCIAL MEDIA ISN'T DESIGNED WITH YOUR LONG-TERM HAPPINESS IN MIND”

● dopamine, which tells our brains that checking social media is worth doing again. And when you add in notifications and alerts, it isn't long before our brains begin to release dopamine just in anticipation of checking our phones.

There's no shortage of dopamine triggers baked into the design of the social media apps. 'Like' buttons take advantage of both our desire for social validation and our love of seeing our 'score'. Gamification elements, such as Snapchat's 'streaks' feature, which publicly keeps track of how many days in a row you've used the app, make users feel compelled to check their apps every day in order to keep up their rating.

Our phones and apps also take advantage of our inherent social impulses and anxieties, including our fear of missing out (FOMO) and the impression that we need to reciprocate when we feel someone has done something for us. Take, for example, those ticks on Facebook, WhatsApp and other platforms that indicate when your friend has read your message. Your friend knows you've seen those ticks, so there's

now a social pressure for them to respond. You might even get emails telling you that you have unread messages and notifications, piling on the pressure to log in, lest you miss out on some news or leave someone hanging. And then there are those little dots that indicate when someone is in the process of replying to your message. What's the likelihood you're going to put down your phone before you've seen their response?

TIME FOR CHANGE?

There's no question that these design features are effective. But what's good for profits is not so great for our mental health. Studies have linked excessive social media use to sleep deprivation, anxiety, loneliness and depression in teens, and given the design tricks we've revealed here, this is perhaps no surprise. The attention-based business model of social media platforms means that their goals and the goals of their users are often inherently at odds. “Social media isn't designed with your long-term happiness in mind: it's designed to capture as much of your attention as possible *right now*,” says Kevin Holesh, creator of the *Moment* app.

As long as social media platforms continue to make money by selling our attention, they are unlikely to change their practices on their own. “There's an arms race for attention,” says Alter. “And if you don't use every tool at your disposal to ensnare consumers, you'll be left behind. Short of pressure from consumers or government intervention, it's hard to imagine companies abandoning the hooks that make their products hard to resist.”

ABOVE LEFT:
Crystals of
dopamine. This
neurotransmitter is
released after
eating or having
sex, but it can also
be released
in anticipation
of checking
your phone

ABOVE: Child
development
experts wrote to
Facebook CEO Mark
Zuckerberg asking
him to cancel
Messenger Kids
(right), due to
concerns about the
impact of social
media on children



Thankfully, there are signs of pushback. In January this year, two of Apple's major investors wrote an open letter to the company demanding that it offer better parental controls. Soon thereafter, a group of children's health experts begged Facebook to abandon Messenger Kids, its recently launched platform targeting children under the age of 13. In February, a group of disillusioned tech insiders and investors launched the Center for Humane Technology, an organisation dedicated to advocating – and lobbying for – a more ethical design.

These efforts, if successful, will be slow. But in the meantime, there are things we can – and should – do to develop a healthier relationship with our devices. “If you feed the beast, that beast will destroy you,” said Palihapitiya to his Stanford audience. “If you push back on it, we have a chance to control it and rein it in.” 🐉

Catherine Price is a science journalist and author of *How To Break Up With Your Phone* (£12.99, Trapeze).



DISCOVER MORE



Listen to an interview with Catherine Price on the Science Focus podcast. Visit sciencefocus.com/sciencefocuspodcast or subscribe on iTunes, Acast, Stitcher, or your favourite podcast app.





PLANET EARTH'S FERTILITY PROBLEM

Roughly one in six couples in the UK has problems conceiving. Our fertility is waning. And we're not the only ones who are struggling – many other species are too...

WORDS: JHENI OSMAN

Pollution and sexually transmitted infections (STIs) are making humans sterile. At least that's the case in the dystopian world of *The Handmaid's Tale*, where the heroine Offred is forced to live as a concubine under a dictatorship – one of the 'handmaids' made to reproduce to keep the birth rate up.

While the book, and subsequent hugely successful television series, can be dismissed as pure fiction, the causes for infertility aren't far off the truth. In the real world, infertility is becoming a major problem in the West. The finger is being pointed at diseases like chlamydia, and environmental factors such as pollution. Fiction seems like it's becoming fact.

Women traditionally shouldered the blame for infertility – after all, they are the ones who are born ●

• with a finite number of eggs. Once these are gone, the biological clock stops ticking and the menopause hits, whereas men produce a completely fresh batch of semen about every 12 weeks (this is how long it takes for sperm to fully mature). But men also have a ticking clock, and they aren't as virile as they used to be.

Last year, a team of researchers led by Dr Hagai Levine published a study in *Human Reproduction Update*. They said sperm counts in the West have more than halved in the past 40 years and are dropping by an average of 1.4 per cent every year, with no sign of abating. Their results showed a 52 per cent drop in sperm concentration, and a 59 per cent decline in total sperm count, among men from North America, Europe, Australia and New Zealand.

Dr Shanna Swan, who was part of the team, says that human-made compounds are partly to blame: "There is a large literature showing that chemicals in the environment and the workplace can decrease semen quality, including concentration. The most dramatic of these are occupational, because the doses are higher, but there is also a lot of data on, for example, pesticides, heavy metals and plasticisers."

THE PLASTIC PROBLEM

Chemicals called phthalates are found in plastics all around us – from food packaging to fragrance, cleaning products to cosmetics, and shower curtains to car dashboards. About 450,000,000kg of phthalates are produced every year and are used to make plastics

"SPERM COUNTS IN THE WEST HAVE MORE THAN HALVED IN THE PAST 40 YEARS"

more flexible, transparent and durable, and we may inadvertently consume them when we eat food that has come into contact with phthalate-containing packaging. Phthalates are so ubiquitous that they can be detected in the urine of about 95 per cent of us.

Phthalates have been linked to all sorts of health conditions, including infertility. As far back as 2003, a study showed that exposure of lab rats to certain phthalates during pregnancy affected the development of the testes of the offspring. Since then, various animal studies have found similar results, which led some scientists to suggest the same might be true in humans. A Swedish study, published in the journal *Environmental Health Perspectives* in 2015, claimed that phthalates caused genital birth defects in boys and impaired reproductive function in adult males.

But others have been more reticent of jumping to conclusions. A study published in *Critical Reviews In Toxicology* in 2013, found that phthalates affected animal hormone concentrations and hence might impact how some reproductive tissues develop. If the same were true in women, phthalates could cause endometriosis – a painful disorder where the tissue that normally lines the inside of the uterus forms

FERTILITY FIGURES



1 in 6

couples in the UK have a problem in conceiving a child



On average,

3 out of 10

sperm cells have abnormalities, while

4 out of 10

are bad swimmers



Men who smoke more than 20 cigarettes a day have a

19%

lower sperm concentration than non-smokers



The male partner is identified as the problem in about

1/2

of couples who struggle to conceive

Age affects male fertility. If his partner is under 30 and he is 30-35 birth rate is

73%

This drops to

46%

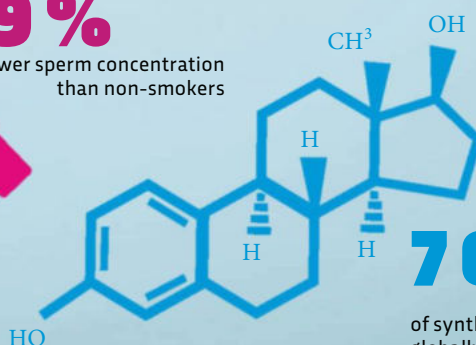
if the man is 40-42



The average woman's fertility decreases by

50%

between the ages of 32 and 40



700kg

of synthetic oestrogens are released globally into the environment every year from birth control pills



In the series *The Handmaid's Tale*, based on the earlier novel by Margaret Atwood, infertility is widespread because of pollution and disease. Handmaids, who wear red, are the few remaining fertile women

outside it. But the researchers pointed out that much higher concentrations would be needed to cause such effects in humans.

Other scientists are completely unconvinced that phthalates are the problem. Prof Richard Sharpe is the principal investigator at the MRC Centre for Reproductive Health at the University of Edinburgh. His team studies how the phthalates to which we're most widely exposed can cause a whole spectrum of reproductive disorders in male rats if their mums are exposed to them. "The adverse reproductive changes result from suppression of testosterone production by the foetal testes," says Sharpe. "But when we looked to see if phthalates could cause similar suppression of testosterone production by the foetal human testes, there was absolutely no effect. This has been confirmed by several other groups. This proves that the human foetal testes are not affected by phthalates like the rat is. There are also no effects after exposing pregnant monkeys to phthalates at comparable doses to rats. The levels we're exposed to are at least 25,000 times lower than the doses needed to induce reproductive disorders in male rats. So the evidence supporting phthalate effects in humans simply does not fit the facts – you have to make numerous presumptions. That is not good science."

Other human-made compounds are also being blamed for infertility. Prof Allan Pacey, from the

University of Sheffield, has been carrying out research on male fertility for a number of years. His most recent results show that glycol ether, a paint solvent, affects fertility. "The risk of men having low motile sperm counts is increased when they are exposed to glycol ether," he says.

Meanwhile, BPA (bisphenol-A) has been named as the 'gender-bending chemical' by the media because of its apparent links to low fertility. The plastic is embedded in all sorts of everyday items, such as water bottles. Back in 2010, scientists at the research centre Kaiser Permanente in California found that Chinese factory workers with greater amounts of BPA in their urine were up to four times more likely to have poor semen quality. And a small study published this year, involving 94 teenagers from various schools across Devon, found that more than 80 per cent of participants had traces of BPA in their bodies. This was despite them trying to avoid the chemical by using glass or steel containers for their food and drink.

CHEMICAL COCKTAILS

And that's the tricky thing – avoiding ingesting such human-made compounds. This is the case for per-fluorochemicals (PFCs), which are compounds that are used to make everyday things more resistant to water, grease and stains, such as your raincoat, pots and pans, or carpets. A study back in 2009 at the University of California found that women with high levels of PFCs in their blood had trouble conceiving. Worryingly, it can take several years for half of the chemical to leave the human body.

The same goes for other species whose fertility is also declining, often due to human-made chemicals leaching into the environment. Let's start close to home. A group of scientists reckon that

RIGHT: PCBs, which were once used to manufacture paint, can still be found in the guts of marine animals



RIGHT: Lab studies have found that male frogs can become feminised when exposed to a particular weedkiller



● environmental factors may be causing a decline in the fertility of man's best friend. Researchers from the University of Nottingham studied a group of stud dogs over 26 years. Not only did they discover that sperm quality fell in that time but, in many of the pups, the testes didn't descend correctly into the scrotum as they matured.

Moving out into the garden. Atrazine, a weedkiller that's banned in the EU but widely used in the US and Australia, could be turning male frogs female. A study back in 2010 by the University of California, Berkeley, found that atrazine interfered with the sexual development of male frogs in the lab, emasculating three-quarters of them and turning 1 in 10 into females. Research leader Prof Tyrone Hayes suggested that this chemical could be contributing to amphibian declines in the wild. The same is happening to fish. Last year, the University of Exeter reported that one-fifth of male fish in English rivers are now displaying both male and female characteristics. At 50 sites across

the country, the researchers found that 20 per cent of the male fish had poor sperm quality and were less aggressive and competitive, meaning they would be unlikely to breed as well. The finger is being pointed at chemicals that produce oestrogen-like effects, which make their way into rivers and streams. The chemicals come from the likes of agricultural and industrial runoff, but also cosmetics and cleaning products – as well as the contraceptive pill. Some scientists have made the leap that if chemicals with oestrogen-like effects are feminising fish, then they could be doing the same to our fellas.

SEA CHANGE

The bad news is that even if we drastically reduce the use of chemicals, they may hang around in the environment for many decades. Take the case of the polar bear. As if habitat loss isn't challenging enough, another pressure keeps it balancing on thin ice. Human-made chemicals called PCBs (polychlorinated biphenyls), which were banned almost 40 years ago, can still be found in the testes and sperm of polar bears. The same goes for cetaceans. PCBs were used to manufacture all sorts of products from paints to paper, but are lethal at high concentrations. Yet even at low levels, they've been proven to interfere with hormones, causing infertility in everything from birds to fish to mammals.

From chemicals to that root of so many 21st-Century problems: climate change. We've all seen the stories: 'Global warming is killing coral reefs', 'Warmer weather is whipping up super-storms'. But behind the headlines is a lesser-known fact – the fertility of many species is declining due to warming temperatures.

During a key period in embryo development of some reptiles, the temperature of the environment determines whether the embryo becomes a female or

RIGHT: While the urine of women taking contraceptive pills is partly responsible for oestrogen in the water, far higher amounts come from agriculture and industry



"LIFESTYLE FACTORS, SUCH AS OBESITY, A SEDENTARY LIFESTYLE AND SMOKING HAVE AN ADVERSE EFFECT ON FERTILITY"

a male. For green sea turtles that pivotal temperature is 29.3°C, below that they are male, above that they are female. In this warming world, the population is being skewed towards females. A study published this year showed that over 99 per cent of juvenile turtles at a key nesting site in northern Australia were female, because sand and sea temperatures are rising. So it seems that, at least in the case of the green sea turtle, it's fast becoming a woman's world.

FERTILE SOLUTIONS

So what can we do about all this? In the case of climate change, we need to cut carbon emissions. Drastic measures include geoengineering the climate with mega-technologies, such as a light-reflecting shield in space. And we all know how we can do our own small bit – use the car less, eat less meat (particularly cows – they're extra gassy), turn down the heating and set the washing machine to eco-mode. But the

Contrary to popular belief, riding a bike will not batter your balls (or your fertility!)



challenge is a big one. No less daunting is protecting wild species from exposure to chemicals, or at least minimising the damage – whether that's by asking gardeners to go easy on the chemicals, or encouraging farmers to tweak their agricultural techniques.

Last year, researchers from Penn State's College of Agricultural Sciences showed that injecting manure into crop fields as opposed to spreading it over the surface significantly reduced the amount of oestrogen in the surface runoff, and hence the amount that made it into the water downstream. If human fertility is also being affected by oestrogen in the water table, then methods like this would benefit us, as well as other species.

In the case of plastics, they can be hard to avoid. But if you're concerned about phthalates then avoid any plastic packaging that has the number '3' in the middle of the recycling symbol and the letters 'V' or 'PVC' underneath, and instead buy organic products packaged in glass. (Although even some milk in glass bottles may have passed through plastic tubes in the factory.) The good news is that research is being done on flexible polymers that don't leach chemicals in the same way, so fingers crossed there will soon be a replacement to phthalates.

Next, tackle your guilty pleasures, as indulgent lifestyles don't help. "Undoubtedly lifestyle factors, such as obesity, a sedentary lifestyle and smoking have an adverse effect [on fertility]," says Swan.

So, ladies, ensure you're eating healthily and cut down on your drinking, don't smoke and don't overdo the exercise (while being fit is important, too many intensive workouts have been linked to fertility problems). Men, cut back on the booze and burgers, quit smoking and get on your bike. Yes – contrary to rumours that cycling affects sperm quality, a study in 2017 of 5,000 cyclists didn't find a link. But buy a pair of baggy boxers, as research suggests that tight underwear could make your testes too toasty, as could hot baths, jacuzzis and saunas. And to bump up your sperm count and quality, research suggests you should be embracing a Mediterranean diet.

But, as Pacey points out: "The problem is that we have no effective therapies to improve male fertility." Fortunately, there are a whole host of ways to tackle low female fertility – from egg-boosting drugs to IVF. As Louise Brown – the first IVF baby – blows out her 40th birthday candles this July, it's worth us remembering that while science is giving humans a helping hand, other creatures on Earth aren't so lucky. 🐢

Jheni Osman is a science writer, author and presenter, and her daughter was born via IVF.

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WHEN THE CHIPS ARE DOWN

For the last few decades, we've been enjoying faster and faster computer speeds, but we've now squeezed as much as we can from silicon chips. We take a look at the tech that could take their place... WORDS: DR PETER BENTLEY



Compared to those of 50 years ago, the computer processors of today are fast. Crazy fast. Their speed has been doubling approximately every two years. This doubling effect is known as Moore's Law, after Gordon Moore, the co-founder of Intel, who predicted this rate of progress back in 1965. If the top speed of cars had followed the same trend since 1965, we would be watching Lewis Hamilton fly around Silverstone at more than 11,000,000,000mph.

For the computer industry, his prediction became a golden rule, perhaps even a self-fulfilling prophecy. The chip manufacturers were inspired to attain the performance Moore's Law forecast. And so they did, inventing ever more impressive ways to shrink the necessary components to fit into smaller and smaller areas of silicon, and speed up the rate at which those components interacted in the process.

Today, thanks to the large-scale integrated circuits used to make the increasingly powerful microprocessors, the computer industry has transformed the world. We have digitised almost every aspect of our lives, from food distribution to transport, and created new technologies that would never have been possible with older processors, such as social media, online gaming, robotics, ●

SHUTTERSTOCK



Google's vast data centres generate a lot of heat, but a network of multicoloured water pipes keeps things cool



“We’re now reaching the end of this amazing technological explosion”

• augmented reality and machine learning.

The continuing advances predicted by Moore’s Law has made these transformations possible. But we’ve become blasé about the extraordinary progress, to the point where many software companies simply assume that it will continue. But as we create more data everyday, we also create the need for vast warehouses of computers,

known as the cloud, to store and process that data. And the more data we produce, the more computing power we need to analyse it.

But the story of runaway progress in silicon can’t continue forever. We’re now reaching the end of this amazing technological explosion and we’re running out of ways to make our computers faster. Despite the remarkable efforts of research engineers, you can only make transistors so small before you run out of room at the bottom. For example, Apple’s A11 chip, one of the best we have today, contains 4.3 billion transistors in an area of 87.66mm². Go much smaller than this and the transistors become so tiny that the effects of quantum physics start to interfere – electrons start to jump around and turn up in places where you don’t want them to be. With so little space, it also becomes difficult to organise the fine structure of the silicon wafer that’s essential to control its electrical properties. Pack in too many transistors and make them work faster and the restricted flow of electrons within the chip can make it so hot that without significant cooling, it will burn itself up.

NEW INNOVATIONS

Chip manufacturers have known about these problems for decades, and have been doing their best to work around them. We used to see microprocessors increase their clock speed (the base operating speed of a computer) every year, to make them compute more quickly. We saw the 25MHz i486 in 1991, the 200MHz Pentium Pro in 1998 and the 3.8GHz Pentium 4 in 2008. But that was about as fast as we could make them tick without them becoming impossible to cool. Since then, manufacturers have had to use multiple cores so processors can do their work in parallel in order to make them work faster – first double-core, then quad-core, 8-core, 16-core and so on.

Today, it has become so difficult and expensive to continue to match the pace of progress predicted by Moore’s Law that almost all chip manufacturers have abandoned the race. It’s no longer cost-effective to continue in this direction and as a result, there’s been a significant decline in research and development labs

working at the cutting-edge of new chip-manufacturing processes. The age of Moore’s Law is nearly over.

Instead, the major manufacturers now focus their efforts on specialised chips that are designed to accelerate specific types of computation. The most common examples of this are the graphics processors. They were originally created to perform many similar calculations in parallel in order to enable the blindingly fast graphics needed for computer games. They have now evolved into general purpose processors, which are used for data analysis and machine learning. Other companies have introduced their own application-specific integrated circuits (ASICs), such as Google’s Tensor Processing Unit. This is a circuit arranged as pods of 256 chips all working in parallel and developed specifically to run machine learning software at industry-leading speeds that Google recently began beta testing.

The end of Moore’s Law should not be seen as the end of progress. Far from it. We now find ourselves in a new era of innovation, where new computer architectures and technologies are being explored seriously for the first time in decades. These new technologies show that while the future of computing may no longer be increasing at an exponential rate, progress is continuing at quite a pace. While this will likely result in faster conventional computation, it may also give us the ability to process information in an entirely new way. Over the following pages, we look at some of the technologies that could revolutionise the world of computing when Moore’s Law takes its curtain call. •

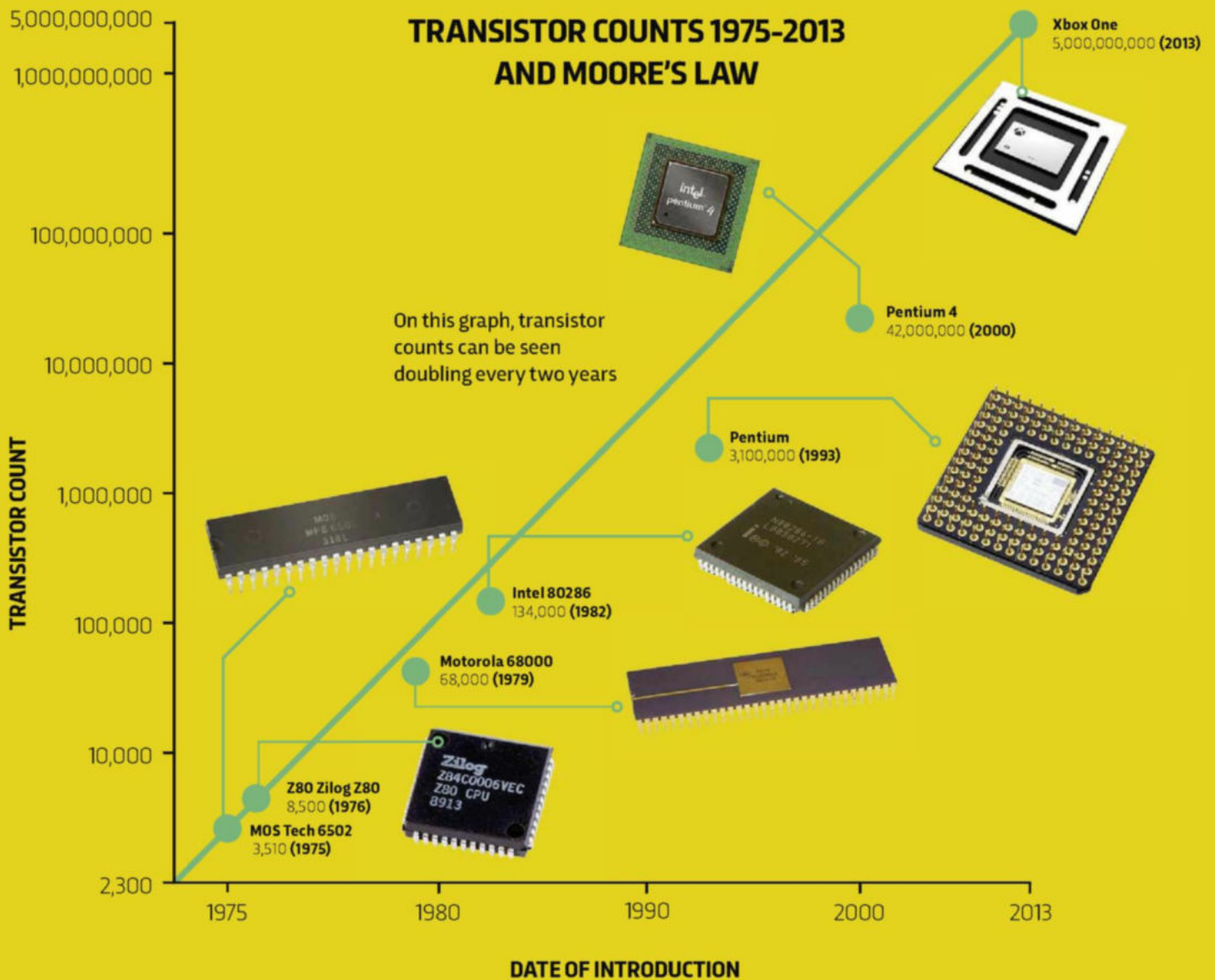
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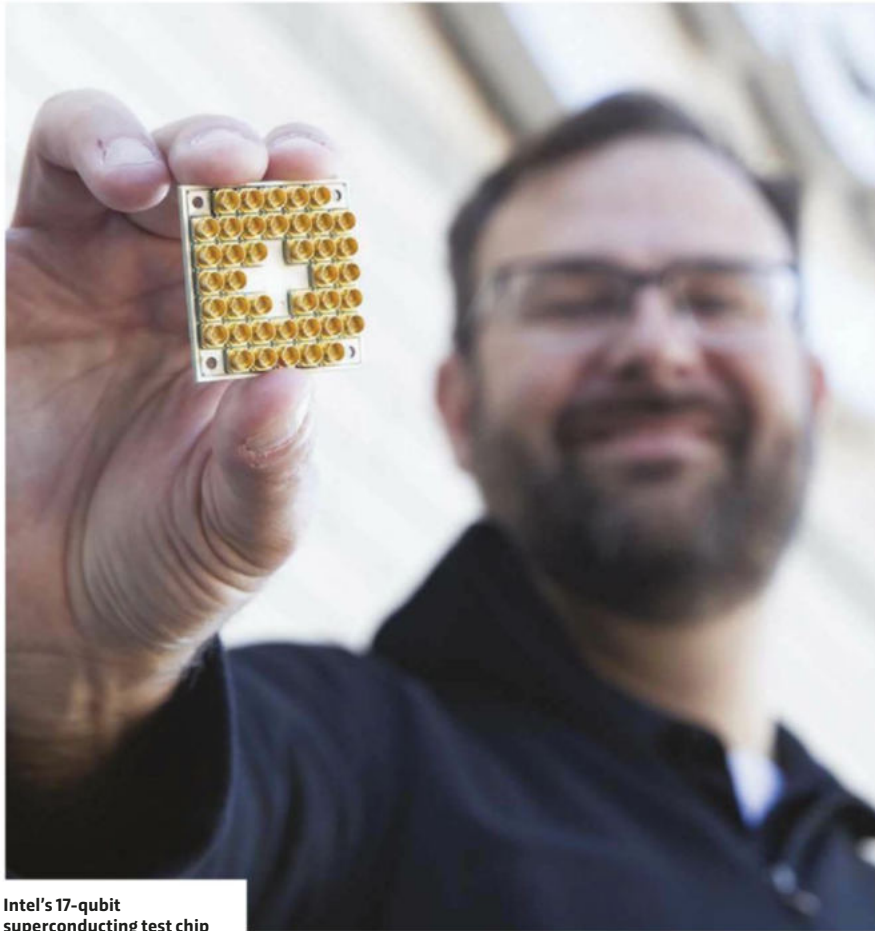
Until we converge on the next generation of processor technology, we continue to eke out every ounce of speed from other ideas. There are now increasing numbers of exotic processor designs for specific forms of computation. But making new chips is a slow and expensive process. Field Programmable Gate Arrays (FPGAs) provide an alternative solution. FPGAs are chips that can be reconfigured, allowing us to change their internal circuitry and effectively create new hardware

without manufacturing new chips. FPGA acceleration is being used for increasing numbers of problems, from lightning-fast automatic trading in London, to accelerated machine learning and AI for data analytics. Although not a new technology, the latest FPGAs have larger capacities and can be reconfigured using a language similar to a conventional programming language, allowing anyone to make their own hardware without needing to be an electronics whizz.



LEFT: Gordon Moore, the co-founder of Intel, predicted the rate of growth in computing power that became known as Moore's Law back in 1965





Intel's 17-qubit superconducting test chip

What's next...

QUANTUM COMPUTING

Perhaps the most familiar of all contenders looking to supersede conventional silicon chips is quantum computing. Instead of letting quantum effects prevent our tiny transistors from working, why not build devices that take advantage of the tiny quantum effects to make them work? Rather than the bits (the basic unit of information used in conventional computing) quantum computing relies on building blocks named qubits. Whereas regular bits can only take a value of either 0 or 1, think of the north and south pole on a sphere, a qubit can take any value on the whole surface of the sphere. This allows them to process more information with less energy.

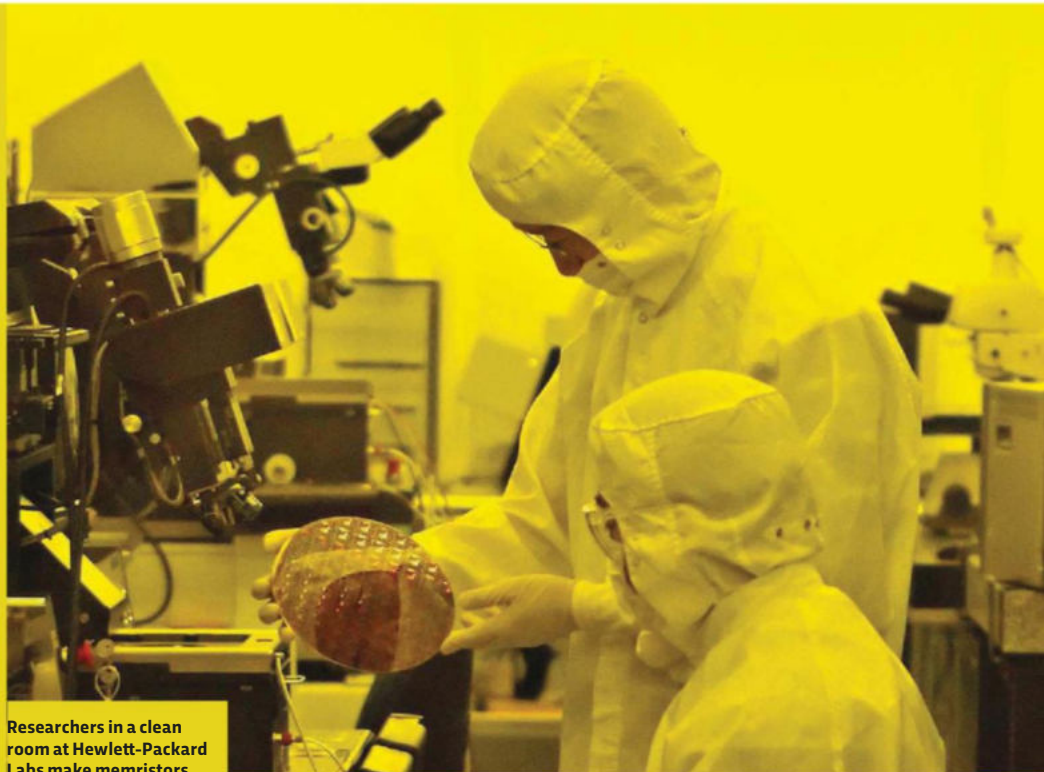
Today there are several early examples of quantum computers that each follow slightly different designs developed by IBM, Google, Rigetti and Intel. So far, it remains to be seen which company and which type of quantum computer will win the race to dominate this exotic new form of computing but initial results certainly look promising.

INTEL CORPORATION, GETTY, IBM, KONIKU

MEMRISTORS

The memristor began life as a hypothetical electronic component, envisioned by a circuit theorist in the early 1970s. The idea was that this component would remember the electrical current that had flowed through it and its resistance would vary according to that history. It was intended to be a fundamental circuit component, just as important as the transistor or capacitor.

When organised in the right way, memristors can replace transistors altogether. As they can be packed in higher densities compared to transistors, they enable faster processors or higher capacity memories. Some regard memristors as the ideal component for modelling neural networks and performing machine learning. Yet despite the theory, it has proven difficult to make memristors. The first commercial ones were released in 2017, though there is some debate over whether they're the same as the hypothesised one.



Researchers in a clean room at Hewlett-Packard Labs make memristors

IBM Research's
graphene-based chip



GRAPHENE PROCESSORS


There are lots of emerging exotic materials that could potentially be put to use in electronics. Graphene – the amazing new material made from a lattice of carbon molecules and is 40 times stronger than diamond – is one such contender because it's a remarkable conductor of electricity.

Recent research by US universities has used graphene to make a transistor that works 1,000 times faster than its silicon cousin. With less electrical resistance, the speed of graphene processors could be increased a thousand-fold and still use less power than conventional technology.



Two of Koniku's
team members

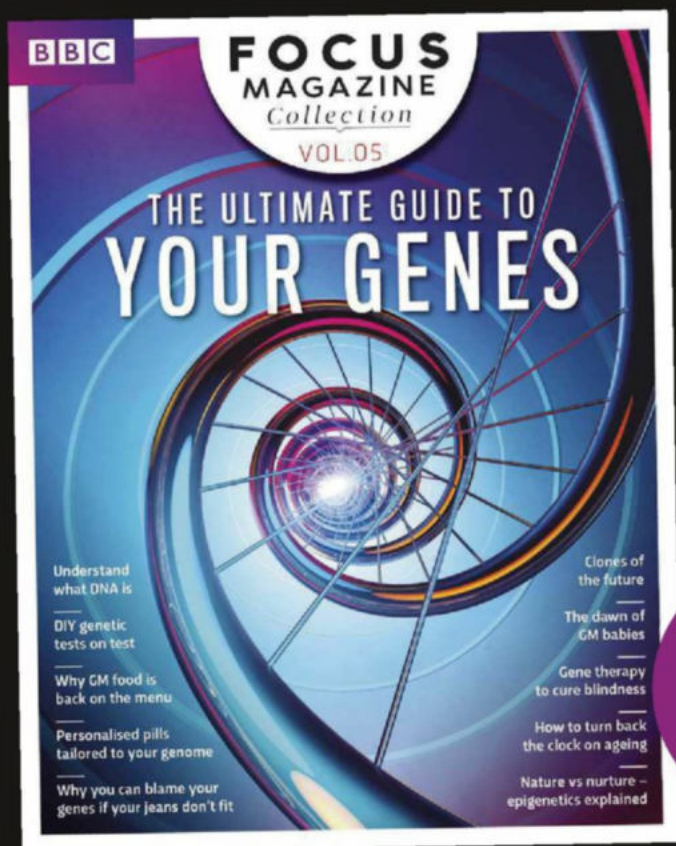
LIVING CHIPS

Many researchers are working on building computers that take inspiration from neurons in the brain. The Human Brain Project, for example, is a massive EU-funded project that's investigating how to build new algorithms and computers that mimic the way the brain works. But some researchers are going even further. Koniku is the first company dedicated to building computers using living neurons. "We take the radical view that you can actually compute with real, biological neurons," says founder Oshioenoya Agabi. Koniku aims to grow living neurons, programmed by altering the DNA, and keep them alive and functional for up to two years in a 'living chip'. The result may be a biological processor that Koniku says could be used to detect the odours of drugs or explosives for security and military purposes. 

Dr Peter Bentley is an honorary professor and teaching fellow at the Department of Computer Science, University College London. His latest book is *Digitized* (£16.99, Oxford University Press).

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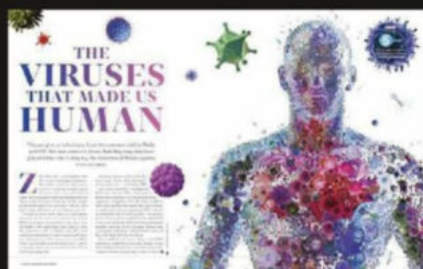
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HELEN CZERSKI... WHY ARE TREES TREE-SHAPED?

"A TREE MUST BE ROBUST ENOUGH TO STAY STANDING UPRIGHT, POSSIBLY FOR CENTURIES"

While running through a leafy park a couple of days ago, I passed dozens of tree species of different sizes and ages, and I was suddenly struck by how fundamentally similar they were. Wide trunks split into smaller branches in the same sort of way. You could guess the height of a tree just by looking at the diameter of its trunk. We would notice immediately if someone drew a tree with branches that were too wide or a trunk that was too thin. What makes a tree look like a tree?

Maximising the sunlight hitting the tree's leaves is obviously critical for the tree's survival. But the size and shape of the branches is mainly determined by a different criterion: a tree must be robust enough to stay standing upright, possibly for centuries.

Imagine an oak tree, with gnarled boughs reaching sideways off the main trunk. Each bough has to support its own considerable weight, so the wood in its lower half is slightly compressed and the top half is being stretched. That top layer of a bough is acting like a guy rope, taking the weight of the branch. And a particular type of wood has grown there to do that job. It's called reaction wood, because it formed as reinforcement to take the increasing weight as the branch grew. The trees that reinforce on top the boughs are the 'lollipop' ones: classic branching species like oaks and sycamore.

But there is another way of solving that problem. Some trees grow their reinforcing reaction wood on the underside instead, so the branch is pushed up, rather than pulled from above. It works, but not as effectively, so these trees can't support large side branches. The ones that reinforce underneath have a thick vertical trunk with much smaller side branches, and they grow to be conical. Some examples of these trees are pines, spruce and firs.



The next problem is the wind. Trees can sway in the breeze, but if they bend too far they'll snap. A thick branch won't bend easily, but it's also heavy – that adds mechanical stress at the point at which it forks off from the rest of the tree. So as the tree branches, there's an ideal ratio of diameters that will minimise the bending throughout the tree. This produces a pattern that has been observed for centuries: if you chop off a forked bit of tree, you'll see that the cut area of the main branch is approximately equal to the cut areas of the two forks added together. This is why we'd notice if a cartoon tree had the 'wrong' branch size – all trees follow the same pattern to minimise the chance of snapping in the wind.

Even the way that branches flex makes the tree more robust. A tall, thin tree with no branches would sway in the wind at a specific rate, putting maximum stress on the trunk at the extremes. But in a branching tree, each branch will sway at its own rate, pushing and pulling on the trunk at different times which are all out of sync. Sharing the energy like this puts less stress on the roots, so the tree is more likely to survive a storm.

I don't think I'll ever run through that park again without getting distracted by the trees. For all the variety in the different species, they all have to contend with the same physical constraints. We generally think of the leaves as what makes a tree beautiful, but once you've seen the ingenuity of the structure, you come to realise that the leaves are just the icing on the cake. **Q**

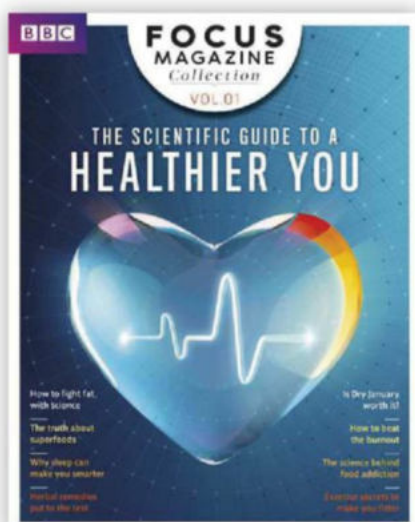
Dr Helen Czerski is a physicist and BBC presenter. Her latest book is *Storm In A Teacup* (£18.99, Transworld).

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YOUR QUESTIONS ANSWERED

MAY 2018

EDITED BY JAMES LLOYD



A monarch spends about 10 to 14 days as a chrysalis before emerging as a butterfly

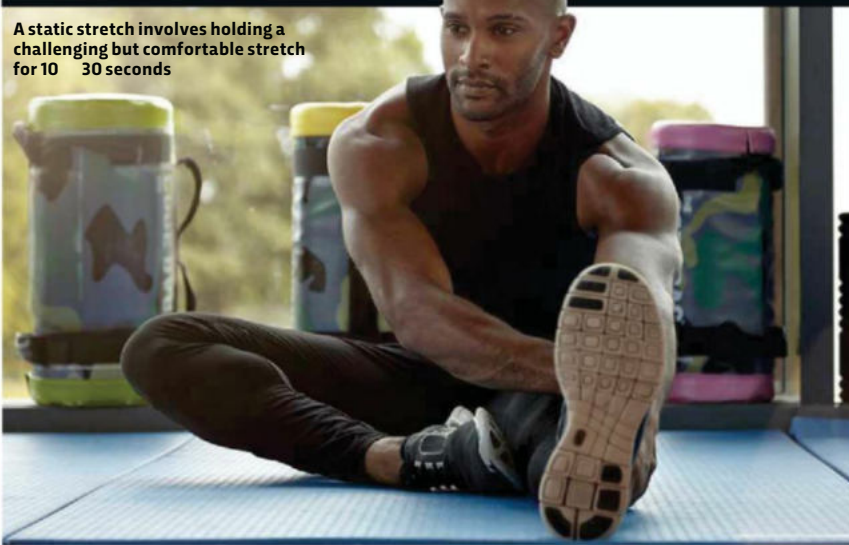
Do animals go through puberty?

BEN CHELSKI, COLCHESTER

Puberty is the process we go through to become reproductively functional. It is characterised by the physical, chemical and sometimes social changes that occur during sexual maturity. Some animals, like the Cabrera's hutia (a rodent that lives in Cuba), reach this point when they get to an exact weight of 360g for females, or 300g for males. But for most other animals, the timing of puberty is age-related. Insects and amphibians

experience 'metamorphosis', going through two or more distinct stages of their development to move from hatching or birth to adulthood. Meanwhile, some aphid and mite species speed things up by being born pregnant, hatching with the next generation of eggs already growing inside them – how weird is that! So it seems puberty, in some form or another, is a shared and necessary evil across the whole of the animal kingdom. cc

A static stretch involves holding a challenging but comfortable stretch for 10–30 seconds



Why is stretching such a pleasure?

PETER TURNER, VIA EMAIL

After a night's sleep or an afternoon spent staring at a computer, there's little better than a good stretch to release tight muscles. Not only does stretching clear your mind by allowing you to focus on your body, it also releases endorphins.

Blood flow to the muscles increases after a long stretch. Muscles are controlled by the nervous system, which has two main components: 'sympathetic' (fight or flight) and 'parasympathetic' (rest and digest). Static stretching increases activity in the parasympathetic nervous system, promoting relaxation. Although the heart rate may rise during a stretch, it tends to decrease after. **ED**

Why do wombats do cube-shaped poos?

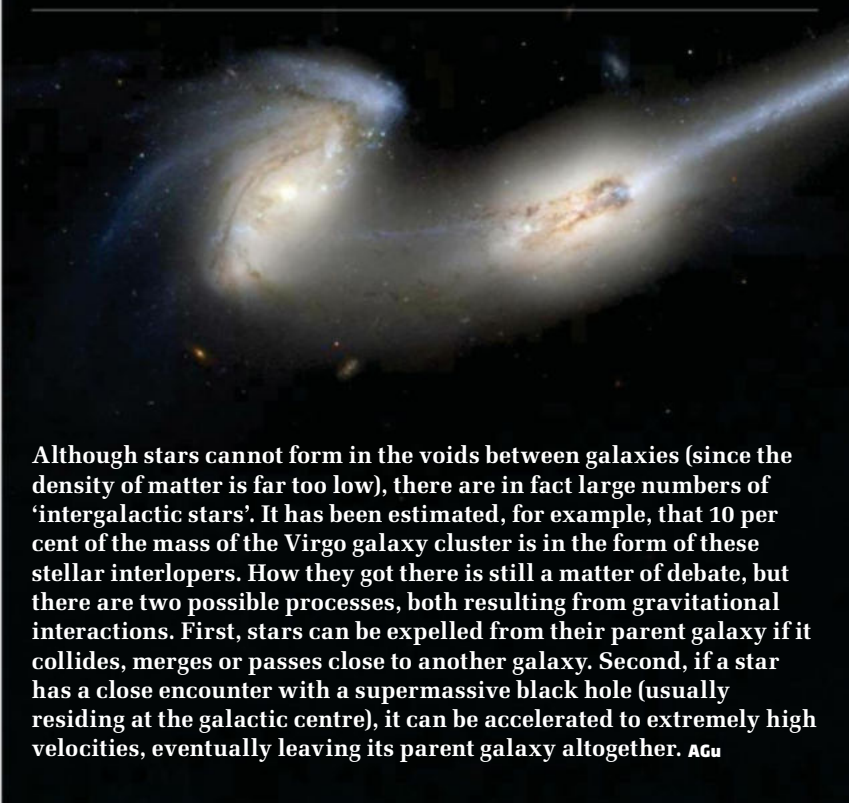
ALEYNA ADAMSON, WIGAN



Wombats are herbivores that are specialised to eat tough roots and grasses. They have an extremely slow digestion that takes up to 14 days to complete. Sitting in the tightly-packed stack of intestines for so long, the faeces form a roughly cuboid shape because it tessellates better into the available space. By the time they exit, the droppings are so dry and hard that the circular anus isn't strong enough to squeeze them into a rounded shape. **LV**

Are there any stars between galaxies?

BRIAN BAKER, HOOK



Although stars cannot form in the voids between galaxies (since the density of matter is far too low), there are in fact large numbers of 'intergalactic stars'. It has been estimated, for example, that 10 per cent of the mass of the Virgo galaxy cluster is in the form of these stellar interlopers. How they got there is still a matter of debate, but there are two possible processes, both resulting from gravitational interactions. First, stars can be expelled from their parent galaxy if it collides, merges or passes close to another galaxy. Second, if a star has a close encounter with a supermassive black hole (usually residing at the galactic centre), it can be accelerated to extremely high velocities, eventually leaving its parent galaxy altogether. **AGU**



Do dogs recognise their own breeds?

MAISIE HARTLEY, BRISTOL

There has been no specific research to ascertain whether dogs can recognise their own breed. But we do know that, smart as our canine friends are, they don't pass the 'mirror test' to understand that they are looking at a reflection of themselves, and so we don't believe that they have a sense of self in the way that dolphins and the great apes do. However, formal research has proved that they *can* differentiate between pictures of dogs versus other species such as rabbits and cows. **CC**



Can you unboil an egg?

BRIAN LISLE, HUDDERSFIELD

When an egg is boiled, the transparent liquid (albumen) around the yolk turns white. That's because the heat has caused the proteins within it to tangle up randomly. In 2015, a team of chemists in the US and Australia showed they could reverse the process. They added urea to liquefy the boiled egg whites, then put them in a vortex device to pull apart the proteins and return them to their original state. It may sound like a party trick, but the technique has important applications in repairing faulty proteins used in medicine and industry. **RM**

What effect does microgravity have on menstruation?

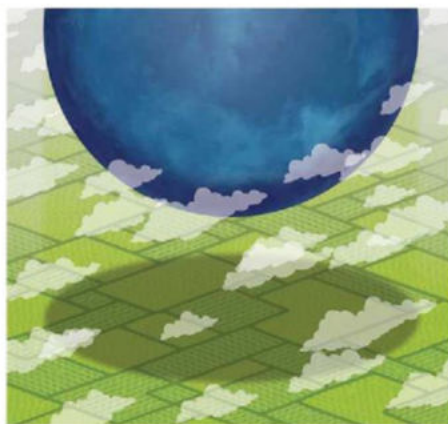
HARRIET WULFF, IRELAND



Microgravity, such as that experienced on the International Space Station, has no effect on the menstrual cycle. In the 1960s, some experts warned against sending women into space over fears that menstruation and PMS could affect their ability to work. There were also concerns that blood might flow back into the body, pooling in the abdomen and causing peritonitis. The fears were unfounded. However, the issue of storing sanitary items, together with limited washing water, means that women in space tend to take oral contraceptive pills to prevent menstruation during their mission. **ED**

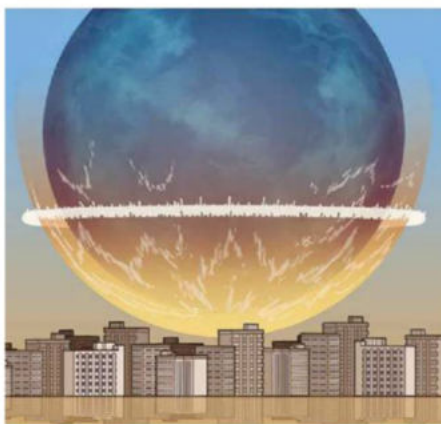
THE THOUGHT EXPERIMENT

WHAT WOULD HAPPEN IF THE UK'S ANNUAL RAINFALL FELL IN ONE GIANT DROP?



1. MASSIVE DROP

The UK receives around 1,200mm of rain per year. That equates to 291 cubic kilometres in total – more than four times the volume of every lake and reservoir in the UK! If you could form it into a single drop, it would be 8km across. From a typical cloud height of 2,000m, this raindrop would take about 30 seconds to fall and would be travelling at 300km/h when it hit the ground.



2. INITIAL IMPACT

The kinetic energy of 291 billion tonnes of water impacting at this speed is about one terrajoule. This is equivalent to 250 megatons of TNT, or almost half as much as the combined energy of every nuclear weapons test in history. If it fell in the middle of the country, Leicester would be instantly incinerated and then smashed flat by a superheated bow wave of compressed air beneath the water bomb.



3. FLOODWATER

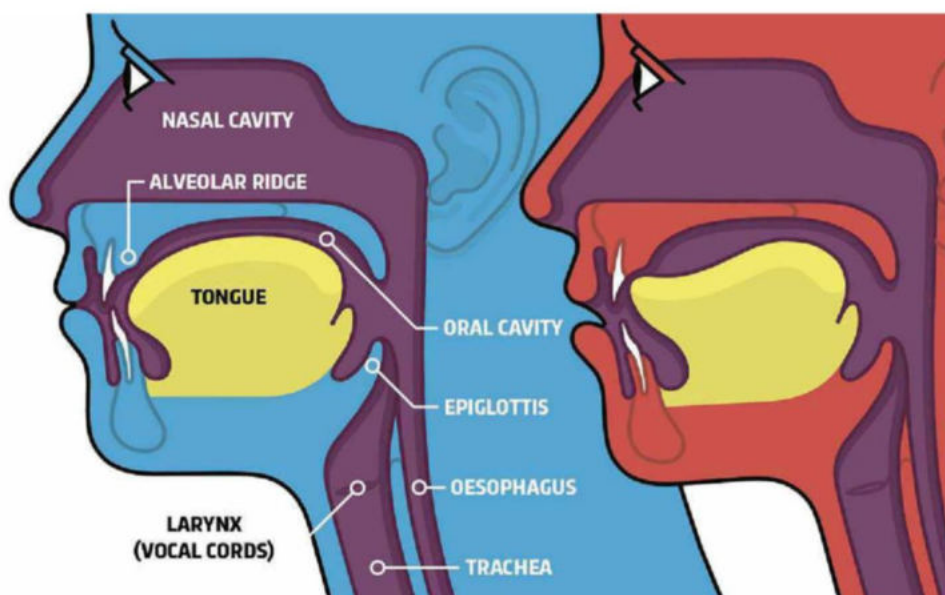
As the drop hits the ground, its upper edge is still at an altitude of 8,000m, and as the water falls inexorably downwards it is forced sideways to form a supersonic tidal wave over a kilometre high. Every tree and building in its path for at least 100km in every direction is torn up. The whole of the Midlands, East Anglia and much of the south of England is flooded to a depth of at least a metre.

Why can't everyone roll their 'r's?

AWA SQUARE, ROCK SPRINGS, WYOMING

It's a misconception that some people are destined never to roll their 'r's. In countries with 'r' rolling languages, many people learn the skill in childhood. Spanish is an example of one such language. However, those yet to master the skill need only to practise. The key is to tuck your tongue behind your upper front teeth, resting the tip on the 'alveolar ridge' – the small, bony protuberance just behind

the teeth. It's also important to relax the tongue so that it vibrates as the air flows past. Rolling an 'r' is strikingly similar to blowing a raspberry. In fact, some language experts suggest beginning training by blowing a raspberry while humming, or doing a lip trill while moving the tongue up. Be prepared for hours of practise, but perhaps not in the office, unless you have understanding colleagues! **ED**



If we were able to dig to Australia, at what point would you stop digging down and start digging up?

CLARE JOHNSON, WEST YORKSHIRE

To dig from London to Sydney, you would actually need to angle about 15° off the vertical, in a roughly easterly direction, so technically you are never digging straight down. Your tunnel would reach its closest point to Earth's centre after about 6,150km and would slope upwards after that. Assuming, of course, that we ignore all the physical impossibilities inherent in such a project. **LV**



QUESTION OF THE MONTH

Large clouds can weigh tonnes. How do they stay up?

TERRY ROCKETT, VIA EMAIL

Air is mostly nitrogen (N_2) and oxygen (O_2), with an average density of 1.225kg/m^3 . A water vapour molecule is much lighter with just one oxygen atom and two hydrogen atoms (H), so its density (at standard temperature and pressure) is only 0.804kg/m^3 . This is why water that evaporates from the sea rises up into the sky in the first place.

At a certain height, the air cools enough for the water vapour to condense into droplets and form visible clouds. The droplets are liquid water, and therefore denser than air, but they are tiny, so they have a low terminal velocity and fall very slowly. A typical cloud only has about 0.5g of water per cubic metre in it, and if the droplets are small enough, they will be kept aloft by the thermals in the cloud as warm air rises from below. Once the droplets have fused together and grown large enough, gravity dominates over buoyancy and they fall as rain. **LV**

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WINNER!

Terry Rockett wins a one-year subscription to Lingvist Unlimited, an AI-enhanced language tutorial system to help you learn French, German, Spanish or Russian (£79.95, lingvist.com) Lingvist Unlimited also offers bespoke tuition for business and medical users.



Damage to a roof in South Yorkshire, following an earthquake in 2008. At 5.2 on the Richter scale, this was one of the strongest earthquakes to hit the UK in recent years, and was widely felt across the country

Why does the UK get earthquakes when we're a long way from a plate boundary?

SCOTT CONNOLLY, EXETER

In February, parts of southwest England and Wales were rocked by the strongest earthquake in a decade. By global standards, it was pretty weak. It measured just 4.4 on the Richter scale and caused no major damage, yet it still shocked many. After all, the UK is far from the edge of any of the tectonic plates which make up the Earth's crust, and where most quakes occur.

Propelled by the heat of the Earth's interior, the Eurasian plate beneath the UK is moving in a westerly direction by around 10mm per year and is riddled with fault lines. These often slip slightly, triggering tremors detectable only with specialist equipment. Around once a decade, however, there's a bigger shift, resulting in a quake that makes the headlines. **RM**

Could we reuse any ISS modules for a Mars mission?

FRANK POL, TAUPO, NEW ZEALAND

It's extremely unlikely. The ISS components were not designed for the kinds of accelerations, or the amounts of radiation, experienced during interplanetary travel, and do not have adequate life support, power supply, fuel storage, docking systems or lander components. It would actually be much cheaper in the long run, and simpler, to build a Mars expedition vehicle from scratch. **AGu**



WHO REALLY DISCOVERED?

CONTINENTAL
DRIFTALFRED
WEGENERABRAHAM
ORTELIUS

In January 1912, the German meteorologist and explorer Alfred Wegener unveiled an astonishing new vision of the Earth's past. According to Wegener, the world we see today is the result of the break-up of a colossal landmass into separate continents, which have been moving around ever since.

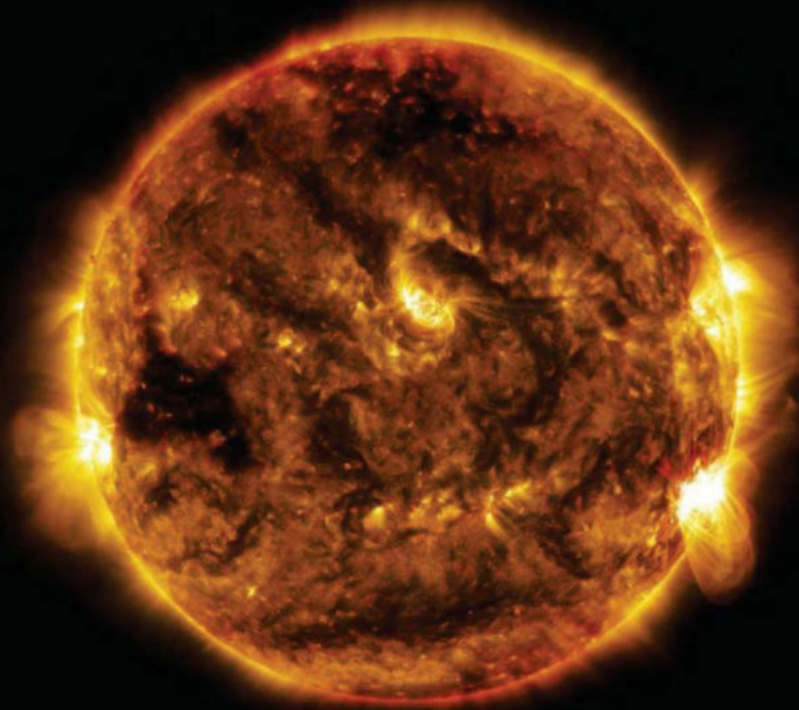
The theory of continental drift provoked outrage, despite the idea having been in circulation for centuries. As long ago as 1596, the Flemish mapmaker Abraham Ortelius had pointed out what doubtless others had already noticed: that the Americas and Africa seem to fit together like jigsaw pieces. He argued this was no coincidence, and that the Americas had been "torn away from Europe and Africa...by earthquakes and floods". In 1858, the French geographer Antonio Snider-Pellegrini went further, pointing out that fossils of similar plants appeared on both sides of the Atlantic. Presaging Wegener, Snider-Pellegrini argued that there had once been a single landmass which had disintegrated, though he ascribed the cause to the biblical Great Flood.

Wegener himself never found a compelling explanation for the driving force of continental drift. But we now know it's down to the roiling motion of vast convective loops of hot rock beneath the Earth's shattered crust. RM



Why doesn't the Sun fuse all its hydrogen at once and explode like an H-bomb?

EDWARD SEYMOUR, HOVE



The Sun is powered by the energy released when the nuclei of its hydrogen atoms slam together so hard they fuse together. As these nuclei are protons with the same positive charge, they repel each other, so it takes incredibly

high temperatures in excess of around 15,000,000°C to persuade them to fuse together. But such conditions exist only in the Sun's intensely hot, dense core, which makes up barely 1 per cent of its total volume. RM

How are fragrances removed to make fragrance-free products?

CAROLYN ROBERTS, LIVERPOOL

'Fragrance-free' doesn't mean that a cosmetic product doesn't smell of anything. It means that it doesn't have any fragrance chemicals in it. These might be synthetic fragrances, but they could also be certain natural compounds, such as fruit oils. However, labelling regulations only affect compounds that could cause skin irritation. Other ingredients such as olive oil or shea butter have a mild scent but they don't count as fragrances for the purposes of product description. Cosmetics referred to as *unscented* have been formulated to remove any smell, but they do this by adding masking chemicals, such as phthalates, rather than removing the scent molecules. LV



An aerial night photograph of a city grid, specifically the Eixample district in Barcelona. The image shows a dense arrangement of buildings with red-tiled roofs, illuminated by warm yellow streetlights. The grid pattern is characterized by chamfered (octagonal) corners at the intersections, which are clearly visible. A large, dark, rectangular building with a flat roof is prominent in the center of the grid. The overall scene is a high-angle, top-down view of the urban layout.

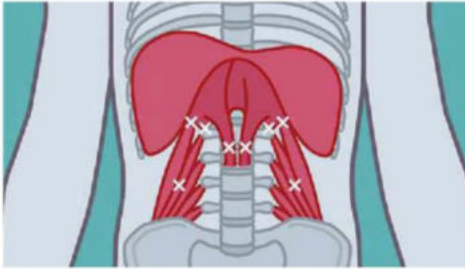
WHAT IS THIS?

Barcelona at dusk

The highly organised fashion of Barcelona's bustling streets is only revealed when the city is viewed from above, as captured here by a drone. This district is known as Eixample and was designed by pioneering city planner Ildefons Cerdà to maximise sunlight and ventilation, while the chamfered corners improve visibility at junctions.

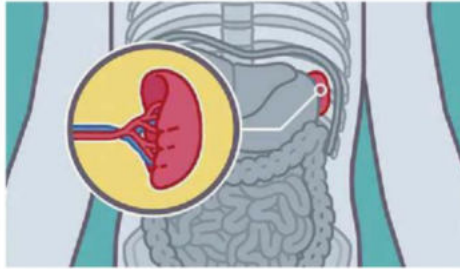
...I GET A STITCH?

A stitch is a sharp, stabbing pain just under the ribcage. It strikes when exercising, and is twice as likely to occur on the right side of the body as the left. Remedies for stitches are mentioned as far back as Pliny the Elder, but so far the exact cause has only been narrowed down to three main possibilities: a) strained diaphragm ligaments, b) restricted blood flow, and c) irritation of the membrane surrounding the abdominal organs. **LV**



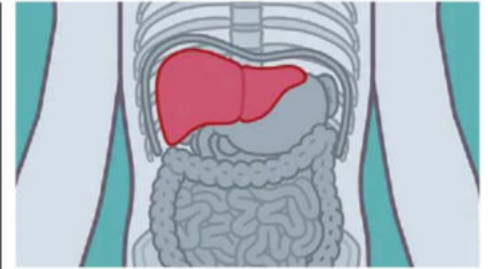
1. Diaphragm (theory a)

Running on a full stomach may jolt the ligaments supporting the abdominal organs, which strains the diaphragm. But stitches are also common in swimmers, where there's no jolting.



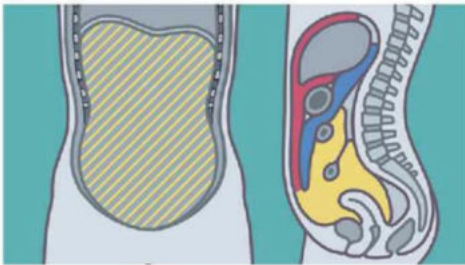
2. Spleen (theory b)

Increased heart rate during exercise forces extra blood cells into the spleen. This causes it to swell, restricting blood flow to the limbs and diaphragm muscle – another possible source of stitch pain.



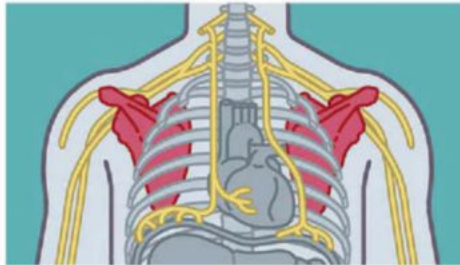
3. Liver (theory b)

Likewise, the liver also blocks blood flow as it swells. The liver sits on the right, which may explain why stitches are mostly on that side of the body.



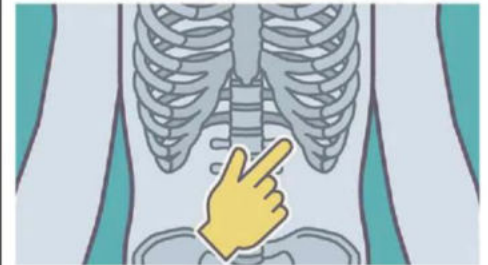
4. Peritoneum (theory c)

This membrane surrounds your abdominal organs and may become irritated as it rubs against your side. Sugary drinks seem to exacerbate this.



5. Right shoulder blade

Stitches often cause a phantom or 'referred' pain in the shoulder, because the phrenic nerve from the diaphragm also connects the shoulder.



6. Ribcage

The quickest way to ease a stitch is to press firmly upwards, underneath your ribs. It isn't clear why this helps though.

Is it better to walk or run in the rain?

TONY HERSH, NEWBURY

It's a question many of us ask when caught in a downpour: is it better to run and get to shelter quicker, or does running mean we encounter more raindrops and get wetter?

The amount of rain striking the top of your head each second depends only on how hard it's raining. So, although running faster won't change the rate at which you get wet, it will get you to shelter quicker, minimising your exposure to the rain and keeping you drier. Meanwhile, as you head for shelter, the front of your body also cuts through rain and gets wet. But the total amount of rain you travel through depends only on the distance between you and shelter, and has nothing to do with your speed.

Things do get more complicated as you add in the effect of wind speed and direction, but as a rule of thumb, the intuitive answer is right: run towards the nearest shelter as fast as possible. **RM**



IN NUMBERS

400,000

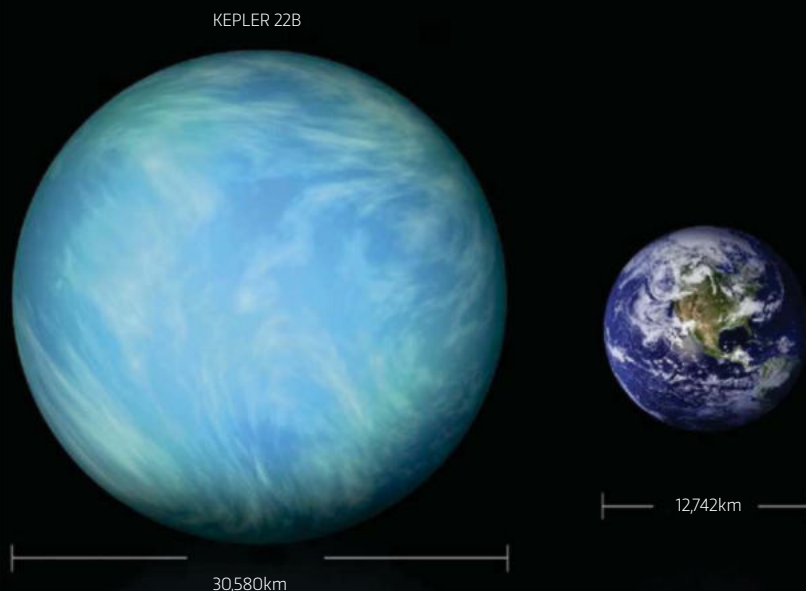
The size, in km², of the hydrocarbon sea Kraken Mare, located on Saturn's moon Titan. (For comparison, the UK is around 243,000km².)

79,000

The mass, in tonnes, of waste in the Great Pacific Garbage Patch.

How do scientists weigh a planet?

PAUL SCANLAN, KENT



We can weigh a planet (or, more correctly, find its 'mass') by using Newton's Law of Gravitation. This law tells us that a planet exerts a gravitational pull that is proportional to its mass. If the planet has a moon, then this gravitational pull must be balanced by the centripetal force that keeps the moon in orbit. In this case we only need to measure the moon's orbital period and the distance between the planet and its moon to reveal the planet's mass. For planets without moons, we can still use their effect on other planets to infer their masses. **AGu**



Do birds wee?

SMERA AHUJA, WINCHESTER

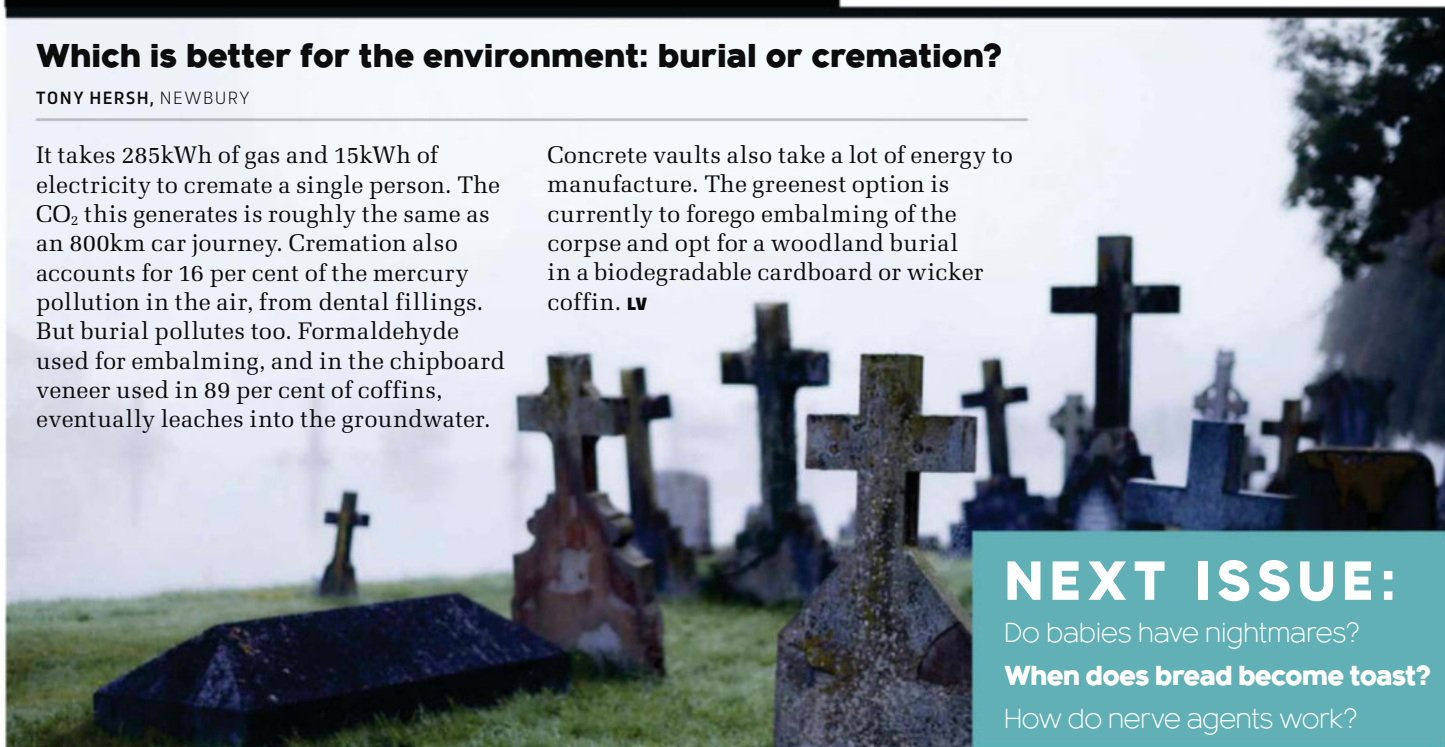
Yes, but not like we do! Birds get rid of excess nitrogen by converting it into a paste-like substance called uric acid. This is less toxic than the urea we produce, and for good reason – unhatched chicks wouldn't be able to tolerate the urea building up inside their shells. Also, doing away with the need for a bladder is beneficial to birds because it reduces their load when flying. Birds have just one waste opening, the cloaca, and this is why you see the white, chalky uric acid mixed in with the dark faecal matter. Interestingly, reptiles also deal with their waste in the same way. **cc**

Which is better for the environment: burial or cremation?

TONY HERSH, NEWBURY

It takes 285kWh of gas and 15kWh of electricity to cremate a single person. The CO₂ this generates is roughly the same as an 800km car journey. Cremation also accounts for 16 per cent of the mercury pollution in the air, from dental fillings. But burial pollutes too. Formaldehyde used for embalming, and in the chipboard veneer used in 89 per cent of coffins, eventually leaches into the groundwater.

Concrete vaults also take a lot of energy to manufacture. The greenest option is currently to forego embalming of the corpse and opt for a woodland burial in a biodegradable cardboard or wicker coffin. **lv**



NEXT ISSUE:

Do babies have nightmares?

When does bread become toast?

How do nerve agents work?

Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

MAY 2018

EDITED BY HELEN GLENNY



GEAR UP FOR A SUMMER OF SCIENCE

Swap your lab coats and Bunsen burners for glow sticks and fancy drinks – a new kind of science event has arrived and there isn't a museum in sight. This summer is packed full of fun for the festival-goer who wants to learn from fascinating speakers and big thinkers in-between music and light shows. First up, there's Bluedot, which involves four days of revelry in the shadow of the Lovell Telescope at the Jodrell Bank

Observatory in Cheshire. There you'll learn how to save bumblebees and find a fresh perspective on climate change. Or if you'd prefer, you can take in a talk by Richard Dawkins, Jim Al-Khalili or Alice Roberts before dancing the night away to sets from The Chemical Brothers and The Flaming Lips. The *BBC Focus* team will also be on hand to add to the fun and help pitch tents... in exchange for subscriptions or beverages.

01

BLUEDOT

JODRELL BANK OBSERVATORY, CHESHIRE

19-22 JULY

DISCOVERTHEBLUEDOT.COM

SCOTT SALT



02

VISIT THE BEST OF THE REST

Round up your family and friends and head to countryside for a mix of science, sounds and sunshine

LATITUDE

HENHAM PARK, SOUTHWOLD, SUFFOLK
12-15 JULY 2018
LATITUDEFESTIVAL.COM

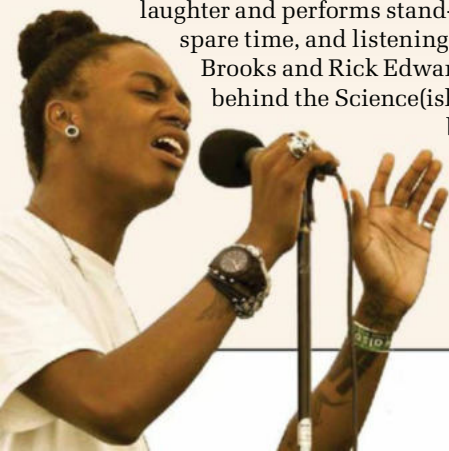
While you're getting your music fix from The Killers and alt-J, the kids can experiment with science in the Wildlife, Weird Science and Adventure area. They can monitor brain activity and develop their surgical skills with a life-sized game of *Operation*. Sounds awesome!



ALSO FESTIVAL

PARK FARM, COMPTON VERNEY, WARWICKSHIRE
29 JUNE - 1 JULY
ALSO-FESTIVAL.COM

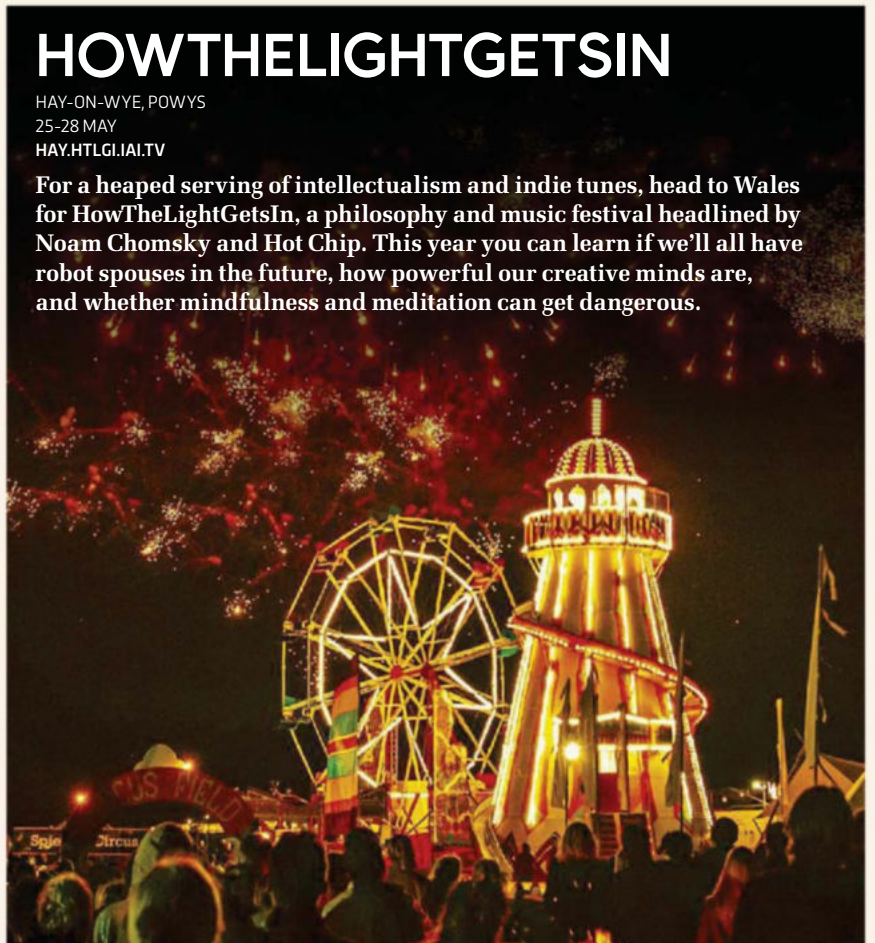
Nestled into a lakeside patch of wilderness in Warwickshire, Also Festival is a place to camp out and discuss big ideas. You can look forward to having a laugh with Sophie Scott, a neuroscientist who studies laughter and performs stand-up comedy in her spare time, and listening to Dr Michael Brooks and Rick Edwards, the brains behind the Science(ish) podcast. In between, there's music, wild swimming and a wine masterclass.

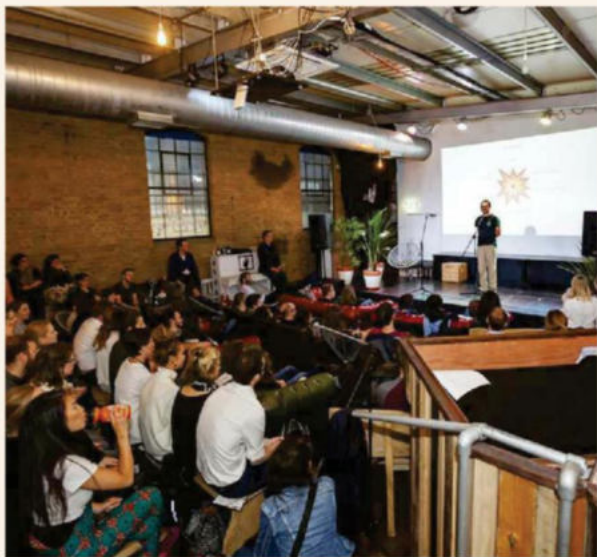


HOWTHELIGHTGETSIN

HAY-ON-WYE, POWYS
25-28 MAY
HAY.HTLGLIATV

For a heaped serving of intellectualism and indie tunes, head to Wales for HowTheLightGetsIn, a philosophy and music festival headlined by Noam Chomsky and Hot Chip. This year you can learn if we'll all have robot spouses in the future, how powerful our creative minds are, and whether mindfulness and meditation can get dangerous.





PINT OF SCIENCE

VARIOUS LOCATIONS AROUND THE UK
14-16 MAY
PINTOFSCIENCE.CO.UK

As the world's largest festival of public science talks, Pint of Science drags all kinds of researchers into your local pub. Alongside the talks there are experiments, quizzes, comedy and games... and beer, of course.

CAMP WILDFIRE

31 AUGUST – 3 SEPTEMBER
WEST KINGSDOWN, KENT
CAMPWILDFIRE.CO.UK

For science that doesn't feel like science, get along to Camp Wildfire – touted as half adventure camp, half music festival. You can learn a bit about astronomy, beekeeping, Sun printing and tin piercing or switch over to more adventurous pursuits, such as wild dodgeball, fire lighting, swing dance and extreme water sliding.



DEER SHED FESTIVAL

BALDERSBY PARK, NORTH YORKSHIRE
20-22 JULY
DEERSHEDFESTIVAL.COM

Deer Shed's family-friendly line-up is full of hands-on science that rolls into this year's theme: making waves. Join a team of diving detectives to investigate the mysterious disappearance of a submarine and its crew, or play around with wave manipulation with madcap mechanic Johnny White. It's worth drying yourself off for slime making, stone skipping and exploring the sonic art installations in the sound garden.



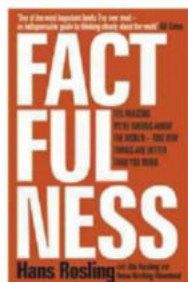
WIN

BLUEDOT TICKETS

Head to our website for your chance to win two Bluedot weekend camping tickets
bit.ly/bluedot2018comp

03

FACTFULNESS
BY HANS
ROSLING, WITH
OLA ROSLING AND
ANNA ROSLING
RÖNNLUND
OUT NOW
(£12.99, SCEPTRE)



BE FACTFUL

When asked simple questions about the state of the world, we usually get the answers wrong. So wrong, in fact, that chimpanzees choosing answers at random score better than us. HELEN GLENNY asks ANNA ROSLING RÖNNLUND why this is the case...

You tell us, in *Factfulness*, that when we're asked simple questions about global trends, most of the time, we get the answers wrong.

Yes. For example, we asked how many years girls go to school for compared to boys. Boys go to school for 10 years, as a global average, so what about girls: three, six or nine years? Most people pick three or six, when nine is the correct answer. It's less than boys, but it's close. We're not just wrong, we're systematically wrong – the results are not random. When faced with an answer they didn't know, most people pick the worst option.

Why do you think that is?

We have this dramatic view of the world, we see war, violence, natural disasters, corruption... Things are bad and it feels as if they're getting worse, right? Most of the news we see is correct, but to become news it has to be something extraordinary. So that's the exposure problem.

The other factor is how our brains collect information. We tend to be very story-driven and interested in horrible events. So they're the ones that stick. When we were hunter-gatherers it was important for us to observe everything happening around us that seemed scary or distracting, so we developed this negative, fear-driven way of seeing the world. But these dramatic instincts don't apply today.

You outline 10 dramatic instincts. Tell us about a few of them.

The 'Gap Instinct', for example, is our tendency to think about the world as divided into two extremes: poor vs rich, developing vs developed. Another is the 'Destiny Instinct'. It's the idea that innate characteristics determine the destinies of people, countries,



Anna Rosling
Rönnlund, who
worked with author
Hans Rosling on
Factfulness

religions or cultures. It's the idea that things are as they are for inescapable reasons: that they've always been this way and will never change.

So how can we be more 'factful'?

We've created thinking tools to help you control your dramatic instincts better.

For example, when it comes to the 'Gap Instinct', we need to remember that although the two extremes exist, most things happen in between on a gradual scale. Today, 75 per cent of people live in middle-income countries. Not poor, not rich, but somewhere in the middle. At one end of the scale there are still countries in which the majority of people live in extreme and unacceptable poverty; at the other is the wealthy world. But the vast majority of us live somewhere in between those two extremes.

With the 'Destiny Instinct', factfulness is recognising that many things appear to be constant just because change happens so slowly. But look at the values around gay marriage or women's right to vote. Even small, slow changes gradually add up to big change. If you want to be reminded of just how much values have changed, talk to your grandparents and think about how their values differ from yours.

Should we be more hopeful about the future of the world?

Our book is not purely positive. We recognise that there are huge challenges for the future. But our dramatic worldview is so negative and terrifying. When we have a fact-based worldview, we can see that the world isn't as bad as it seems – and we can see what we have to do to keep making it better.

04

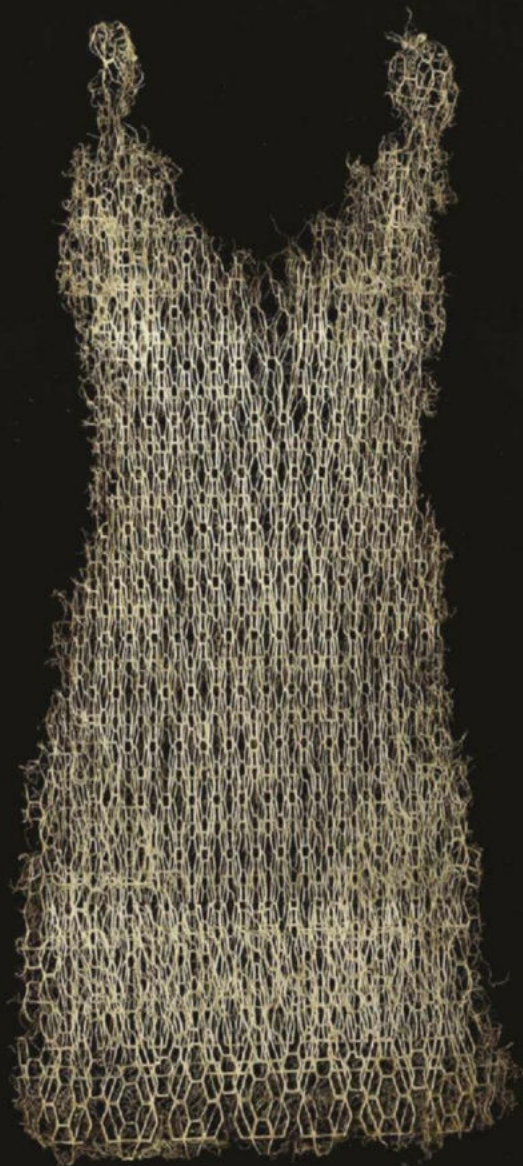
FASHIONED FROM NATURE
VICTORIA & ALBERT MUSEUM, LONDON
21 APRIL 2018 – 27 JANUARY 2019

DRESS NATURALLY

Would you use a bag made from pineapple fibres? How about wearing a leather-substitute made from wine industry grape-waste? You can see both of these and more at the Victoria & Albert Museum, in an exhibition called *Fashioned From Nature*.

Although the fashion industry draws on nature for inspiration, it also relies on environmentally damaging and often contentious raw materials (such as a pair of earrings made in 1875 from the heads of two honeycreeper birds, or a dress from 1860 decorated with the iridescent green wing cases of hundreds of jewel beetles).

But it's not all bad. As well as showcasing what we can learn from the past, the exhibition looks at what designers are doing now to safeguard the environment for the future. Innovative fabrics are on display, including a tunic and trouser set made from synthetic spider silk and a gown by artist Diana Scherer, who trains plant roots to grow into a textile-like material. There's also a Ferragamo 'Orange Fibre' ensemble made from waste from the Italian citrus industry and a bioluminescent dress made from genetically engineered silk.



Artist Diana Scherer created this dress by training plant roots to grow in a certain way



Thank goodness anaesthesia was developed...

05

TEETH
WELLCOME COLLECTION, LONDON
17 MAY – 16 SEPTEMBER 2018

BRUSH UP ON TEETH

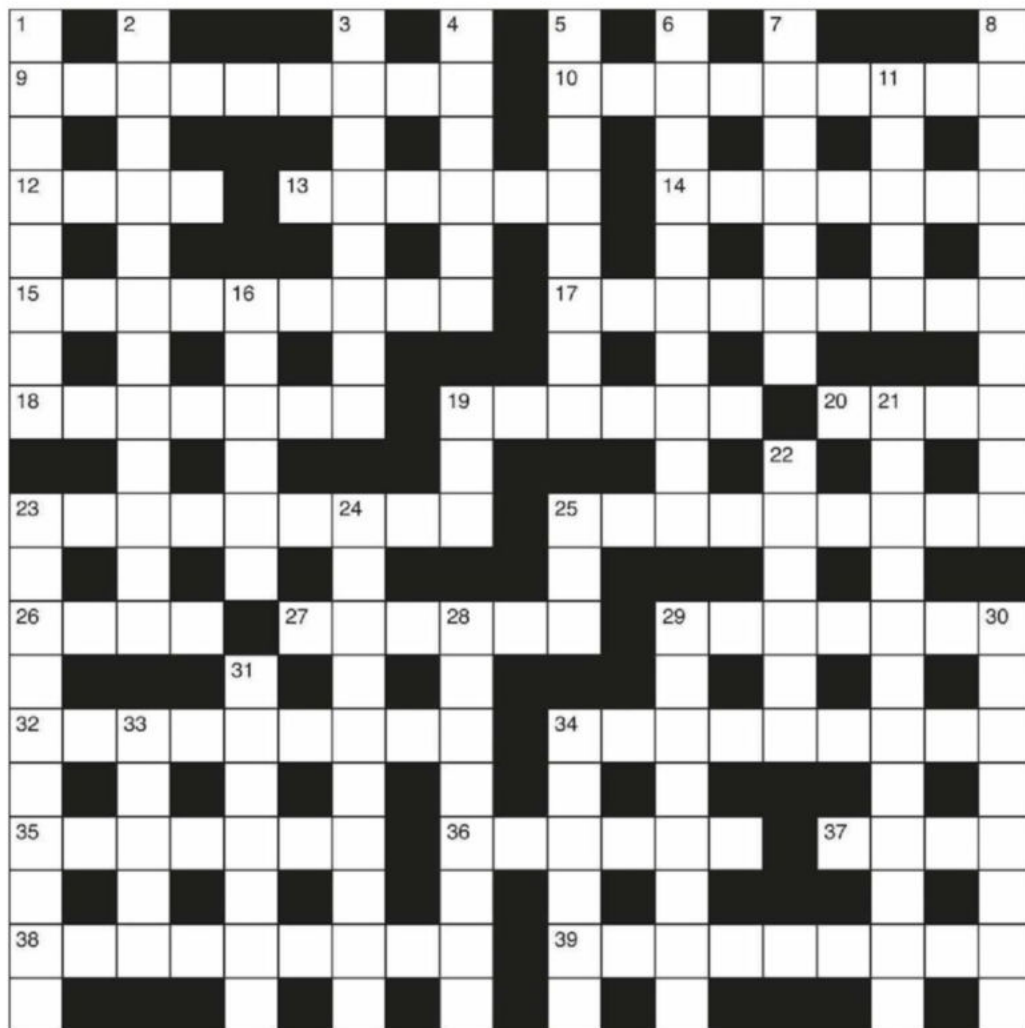
If you cringe at the idea of going to the dentist, you'll find some sympathy at *Teeth*, a Wellcome Collection exhibition opening this month. Those fears have always existed; you'll see ancient Roman artefacts and 19th-Century amulets all designed to protect the bearer against tooth pain, as well the new technologies dentists use to put patients at ease today.

Check out historical tooth care for the wealthy (King William IV's dentures and Napoleon's toothbrush are on display) and marvel at the underqualified barber-surgeons and blacksmiths who pulled teeth for the less privileged. You can track dental technology through the centuries (and let out a massive sigh of relief when you arrive at the advent of anaesthetic).

From oral hygiene campaigns to the competition between dentists and sugar-purveyors, you'll learn something new about your pearly whites, even if you spend the majority of your visit clenching them.

BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



DOWN

- 1 Daft, his changing to take unknown work period (3,5)
- 2 Incompetent maestro has glass, say (3,9)
- 3 Luxurious vehicle doesn't finish in part of France (8)
- 4 I chat about a place in 15 (6)
- 5 Conclusive trial for litmus paper (4,4)
- 6 Socialist finds relevant report on fruit (10)
- 7 Increase low-fat cheese by a particle (2,5)
- 8 Beards must be used by 617 Squadron (10)
- 11 Poet managed to get right word, used figuratively (5)
- 16 A location in the street (6)
- 19 Flyer of character, say (3)
- 21 Strange – at once less sensitive to fuel property (6,6)
- 22 Third-best alloy (6)
- 23 Hearing aid president found in a tree, oddly (3,7)
- 24 Artist turned first to actor playing nobleman (10)
- 25 Atmosphere in Cairo (3)
- 28 Attractive residence filled with loose sand (8)
- 29 Wager a room contains an insulin producer (4,4)
- 30 Worker I left at Sophocles play (8)
- 31 Wife at home turns potato into practical jokes (4-3)
- 33 Group without a safety device (5)
- 34 Bishop has trivial affliction (6)

ACROSS

- 9 Scientist concerned with the body of evidence? (9)
- 10 Queen about to accept a petrol version (9)
- 12 Piece of underwear is a hit (4)
- 13 Very old person has odd arrangement with sailor (6)
- 14 Search Lou out, coming in for a little charge (7)
- 15 Body of water is in Asia in one translation (6,3)
- 17 Strays have roles to play that are perfect (9)
- 18 Bullish character gets brown around a river (7)
- 19 Picture section on plan (6)
- 20 Gap in complete sound (4)
- 23 Attendants to travel in space and time (9)
- 25 Hart treated by doctor, finally – it's an inflammation (9)
- 26 Two artists crammed into a skirt (4)
- 27 Fellow heirs scrambled for shipping area (6)
- 29 Good down under, getting article in windfall (7)
- 32 Canine star, right at home, can be seen twice (3,3,3)
- 34 Enthusiast first spread vegetable (9)
- 35 Detectives moon about, returning in one voice (7)
- 36 Shoot, for a change (6)
- 37 Small cat causes pollution (4)
- 38 Same plot involved with cold, spiritual stuff (9)
- 39 Chap has to permit directions to celebration (9)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.





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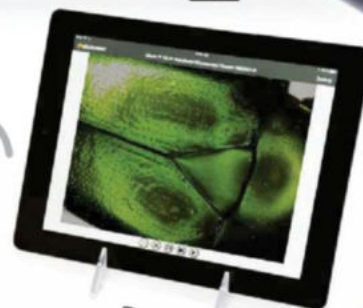
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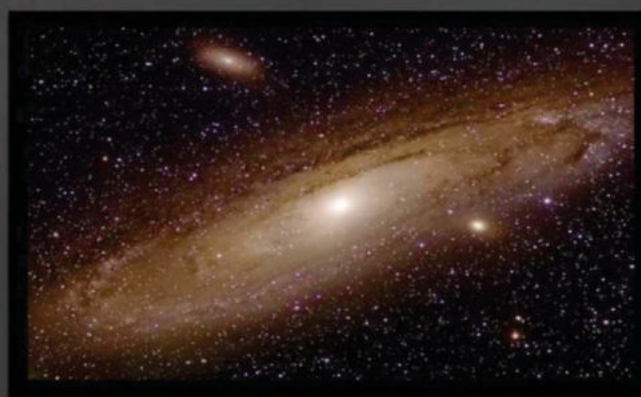
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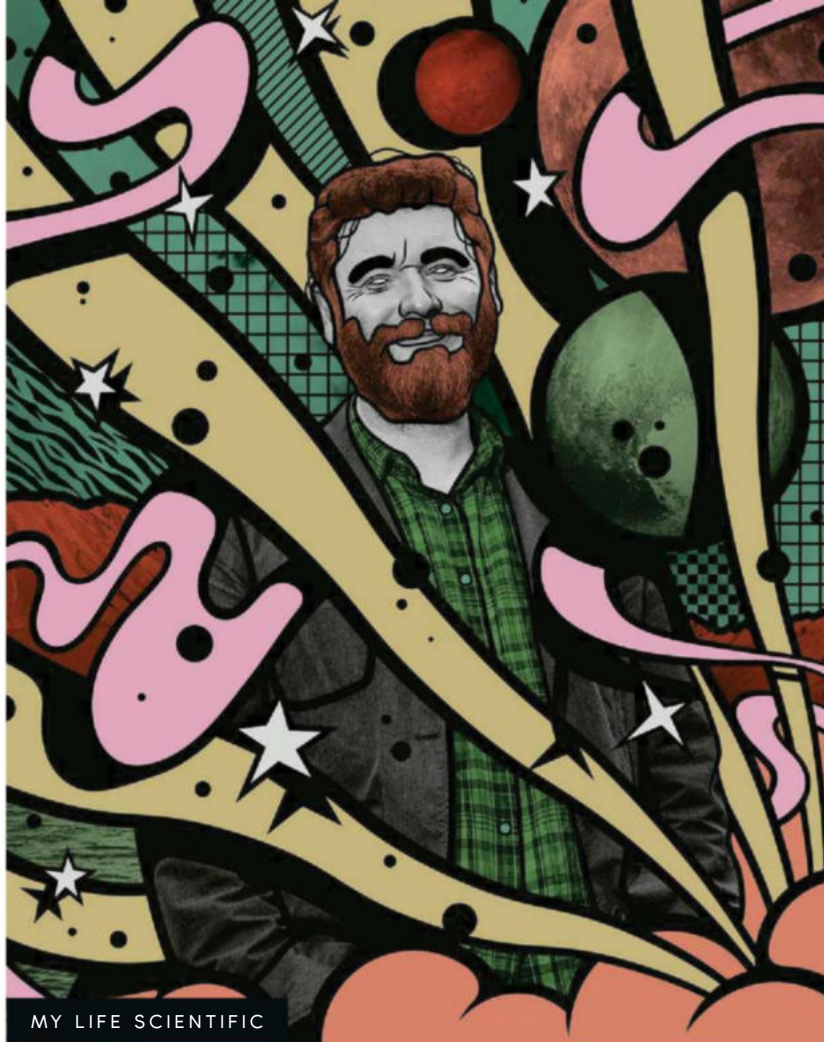
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Prof Tim O'Brien

This month, astronomer **Tim O'Brien** chats to **Helen Pilcher** about his love of space, and the joys of mixing science with music

Tim says it's vital that Jodrell Bank is protected and celebrated. The UK government has applied to get it recognised as a World Heritage Site.

Have you always loved space?

One of my earliest memories is dressing up as an astronaut at primary school. It was 1969 and I was inspired by the Moon landings. The idea that someone could be on this remote celestial body was so exciting. I was lucky to meet Buzz Aldrin on *Stargazing Live*. I told him about how I effectively dressed up as him. He was very nice about it.

Did you want to become an astronaut?

No, I've always been too scared. The reality, that you're essentially strapped on top of a huge bomb, is just too off-putting. That said, if someone could click their fingers and transport me there risk-free, I'd be up for it. I would genuinely love to see the Earth from space.

Best moment of your career?

I'm interested in exploding stars. My PhD was on a particular white dwarf that had one of a series of explosions in 1985. When it exploded the next time, in 2006, the technology had moved on and we were able to gather loads of data and zoom in on what was happening. I remember sitting in a darkened room at Jodrell Bank processing the new data, and seeing an arc of radio emissions coming from this object 5,000 light-years away. We were looking at the shockwave from the explosion, just as we had predicted. We were the first people ever to see this. It was incredibly exciting.

What's the biggest question we have yet to answer?

There are so many interesting questions. What is dark matter? What is dark energy? The fact that we only understand 5 per cent of the

Universe is a bit embarrassing to be honest. The biggest question for me is whether there is extraterrestrial life. At Jodrell, we're starting to sift through our radio telescope data to see if it contains any evidence of extraterrestrial signals.

Do you think there's extraterrestrial life?

Yes. I find it hard to believe that life is such a rare event. Our Milky Way has billions of Earth-like planets, and that's just one galaxy out of hundreds of billions of galaxies in the bit of the Universe that we can see. The Universe extends beyond this. It could even be infinite. There must be something out there.

What's so special about Jodrell Bank?

Over the past 70 years, Jodrell Bank has played a special role in the development of radio astronomy, enabling us to look at the Universe in an entirely new way.

I hear Jodrell Bank has a music festival...

The Bluedot Festival. It started small in 2011 when we were looking for a way to get new audiences interested in science. Now it's grown into a full weekend festival. We have lots of great bands and great science. I even get to introduce some of the bands from stage... I never would have imagined that back when I was in Manchester listening to The Smiths!

Favourite space-themed song?

There are so many to choose from. We're going to put together a list of space-themed songs for this year's Bluedot. I like *Do You Realise?* by The Flaming Lips and *Space Is Deep* by Hawkwind. Of course, I can't claim that it's my favourite, but I have made my own record. A techno remix of space sounds called *Hello Moon, Can You Hear Me?*

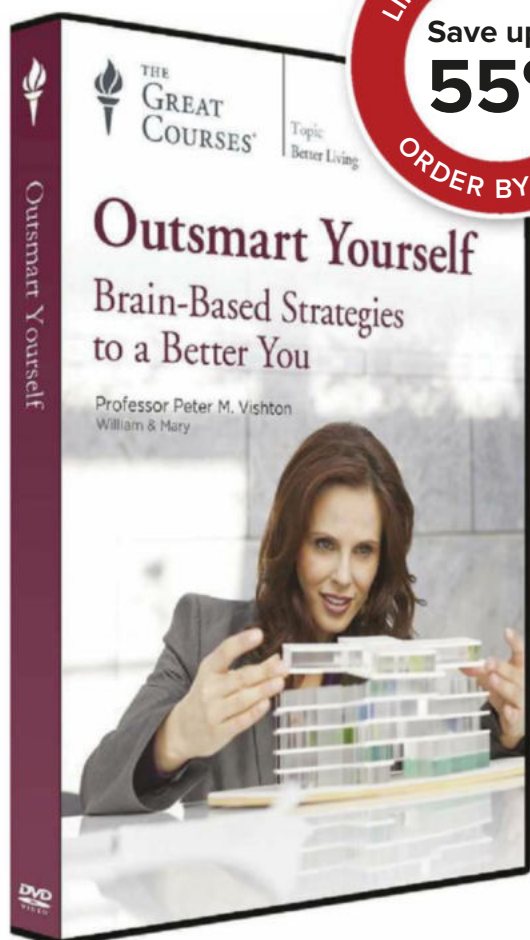
Prof Tim O'Brien is an astrophysicist at the University of Manchester and associate director of the Jodrell Bank Centre for Astrophysics.

DISCOVER MORE



To listen to an episode of *The Life Scientific* with Prof Tim O'Brien, visit bit.ly/tim_obrien

NEXT ISSUE: ROMA AGRAWAL



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